Integrated Vegetation Management for Roadsides

July 1997

Washington State Department of Transportation

Integrated Vegetation Management for Roadsides

July 1997

Washington State Department of Transportation
Field Operations Support Service Center

Project Manager

Raymond Willard
Roadside Maintenance Landscape Architect
Field Operations Support Service Center
Washington State Department of Transportation

Authors

Sheila Daar and Shawn King
IPM Specialists
Bio-Integral Resource Center
Berkeley, California

Copies of the manual area available from:

BIRC
P.O. Box 7414
Berkeley, CA 94707

Phone: (510) 524-2567
Fax: (510) 524-1758
E-mail: birc@igc.org

Introduction

Integrated vegetation management (IVM) can be thought of as quality management for the maintenance of vegetation. The principles and procedures used in IVM are closely aligned those of the Washington State Department of Transportation's (WSDOT) Quality Initiative (Q2000). The procedures and techniques described herein are intended to help the Department improve the quality of roadside management and the quality of our state roadsides.

This document is intended to provide WSDOT maintenance employees with a reference and guidelines for the application of IVM in the day to day work of highway maintenance. It is intended as a tool kit to help answer the questions "Am I doing the right things?" and "Am I doing things right?" It will not be possible to implement an IVM program all at once. The individual maintenance areas and roadside crews will have to begin with selected small applications and expand over a period of years.

The IVM approach focuses on using long-term solutions to establish stable, low-maintenance roadside plant communities compatible with highway safety, maintenance objectives, neighbors' concerns, environmental quality, while at the same time detering invasion of undesirable plants. This is an annually cycling process which includes monitoring, planning, taking action, evaluating, and then making adjustments in the future activities based on the results of monitoring and evaluation. Over time, this practice will reduce habitat for undesirable vegetation on the roadsides and thereby reduce maintenance requirements and cost.

Perhaps the most significant aspect of an IVM program to maintenance employees is the requirement of providing documented observations. The development and habitual use of record keeping that is convenient to use and easily referenced by maintenance personnel is critical to the long-term success of an IVM approach.

WSDOT's commitment to the use of IVM is a response to requirements of the Puget Sound Highway Runoff Program (WAC 173-270) as well as to findings of the Roadside Vegetation Management Environmental Impact Statement (EIS) completed by WSDOT in December 1993. The EIS incited a large response from the public with regard to the use of chemical herbicides. After reviewing seven alternative scenarios for managing vegetation identified in the EIS, WSDOT selected Alternative G, "Locally Based, Long-Term Planning Integrated Vegetation Management," as the basis for future development of the department's vegetation management program. This alternative recommends the use of Integrated Vegetation Management and implementation by individual crews at the maintenance area level.

The release of this document also coincides with the enactment of a law by the 1997 Washington State Legislature requiring that all state agencies and instititions with pest management responsibilities follow the principles of Integrated Pest Management (IPM.) The principles of IPM are the basis for the definition and proposed application of IVM as outlined herein. Therefore, this document also provides an explanation of WSDOT's strategy for compliance with state law in the management of roadside vegetation.

1:P:DP/IVM

Contents

		Page
Chapter 1	**What is Integrated Vegetation Management?**	1-1
	Definition	1-1
	The IVM Decision-Making Process	1-3
	IVM and the Roadside Management Zones	1-11
	Role of IVM in WSDOT	1-11
Chapter 2	**Integrating IVM With the WSDOT Maintenance Program**	2-1
	IVM Begins With the Maintenance Areas	2-1
	Selecting a Series of Initial Locations	2-1
	Approaching the IVM Start-up Phase	2-2
	Implementing an IVM Start-up Program	2-3
	1. Identify the Vegetation Management Objectives	2-3
	2. Develop and Implement a Monitoring Program	2-7
	3. Determine Injury Levels and Action Thresholds	2-10
	4. Apply Least Disruptive Control Tactics and Effective Revegetation Methods	2-13
	5. Evaluate Effectiveness of the Treatments and Adjust Accordingly	2-15
	6. Continue Monitoring and Evaluating	2-15
Chapter 3	**Designing and Implementing a Monitoring Program**	3-1
	What Is a Monitoring Program?	3-1
	Determine if and When Treatment is Needed	3-1
	Select, Time, and Place Treatments	3-2
	Evaluate and Fine-Tune Treatment Actions	3-2
	What Information Should be Collected?	3-3
	Site Background Data	3-3
	Current Conditions: What to Look for When Monitoring	3-5
	How to Gather Monitoring Information	3-8
	Focusing Efforts Where They are Most Needed	3-8
	Levels of Effort Used in Monitoring	3-9
	Planning Monitoring Activities	3-10

		Page
Chapter 4	**Deciding When and Where to Apply Treatments**	4-1
	Introduction	4-1
	Identifying Key Beneficial and Problem Plants	4-1
	Determining Injury Levels	4-2
	On What Does the Injury Level Depend?	4-4
	Determining Action Thresholds	4-6
Chapter 5	**Selecting and Applying Treatments**	5-1
	Vegetation Management: Strategies, Tactics, and Treatments	5-1
	IVM Strategies and Related Tactics	5-2
	Strategies and Tactics for Prevention of Problem Vegetation	5-2
	Weed Suppression Methods	5-10
	Selecting and Applying Treatments	5-26
	Defining Management Objectives	5-26
	Putting It All Together	5-28
	Criteria for Selecting Treatments	5-29
	Applying Treatments	5-31
	Timing Treatments	5-31
	Placement of Treatments: Spot Treatment	5-32
	Determining Treatment Rates	5-32
Chapter 6	**Evaluating the Effectiveness of the IVM Program**	6-1
	Questions to Ask at the End of the Season	6-2
	Cost Effectiveness	6-2
Chapter 7	**Education and Outreach**	7-1
	Introduction	7-1
	Who Needs to Receive Information?	7-1
	IVM Educational Goal	7-2
	Modifying Aesthetic Attitudes Regarding the Appearance of Roadside Vegetation	7-2
	Increasing Tolerance for Presence of Some Weeds	7-4
	Increasing the Understanding of an Ecosystem Approach to Vegetation Management Decisions	7-4
	Focusing on Alternative Treatments Instead of Relying on Herbicides as the First Choice	7-4

		Page
Appendix 1	**IVM Program Forms**	Appendix 1-1
	Forms	Appendix 1-1
Appendix 2	**How to Create and Manage a Successful Test Area**	Appendix 2-1
Appendix 3	**Ways of Qualifying and Quantifying Vegetation Characteristics**	Appendix 3-1
Appendix 4	**Techniques for Visual Monitoring**	Appendix 4-1
Appendix 5	**Tools and Skills Used in Monitoring Activities**	Appendix 5-1
	Sampling Frames for Estimating Cover	Appendix 5-1
	Tools for Estimating Vegetation Height	Appendix 5-2
	Tools for Counting	Appendix 5-2
	Forms	Appendix 5-2
	Plant Identification Keys	Appendix 5-2
	Camera	Appendix 5-3
	Reminders	Appendix 5-3
Appendix 7	**Vegetation Characteristics and Recommendations**	Appendix 7-1
Appendix 8	**State Noxious Weed List**	Appendix 8-1
Appendix 9	**Sources of Information on Biological Control**	Appendix 9-1

Page

Appendix 10	**How to Select an Herbicide for an IVM Program**	Appendix 10-1
	Effectiveness	Appendix 10-1
	Safety	Appendix 10-1
	Mobility	Appendix 10-2
	Residual life	Appendix 10-2
	Selectivity	Appendix 10-2
	Resistance	Appendix 10-2
	Footnotes	Appendix 10-3

WSDOT IVM Manual References References-1

Glossary Glossary-1

2:P:DP/IVM

What Is Integrated Vegetation Management?

Definition

Integrated Vegetation Management (IVM) is a coordinated decision-making and action process that uses the most appropriate vegetation management methods and strategy, along with a monitoring and evaluation system, to achieve roadside maintenance program goals and objectives in an environmentally and economically sound manner.

The IVM process consists of the following principle components:

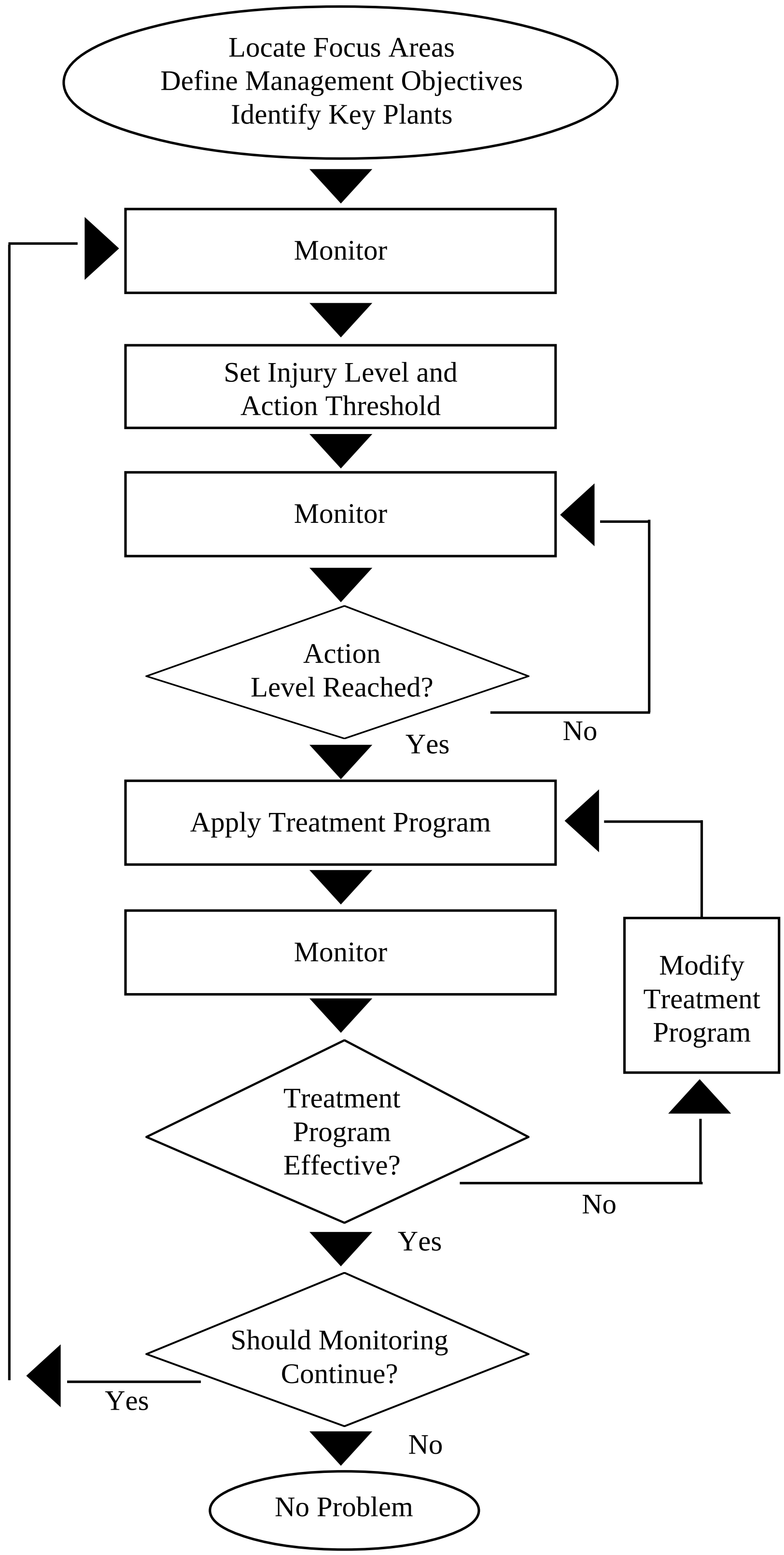
- Monitoring
- Determining injury levels and action thresholds
- Proper timing of maintenance efforts
- Selection of least disruptive control and effective revegetation tactics
- Evaluation

The IVM approach is based on the principles of Integrated Pest Management (IPM). In 1997 the Washington State Legislature passed a law requiring all state agencies to follow the principles of IPM when carrying out pest management activities. (Reference Title 17 Revised Code of Washington, Chapter 357, Laws of 1997, Senate Bill 5077. Effective July 27, 1997.) The use of IPM principles is also identified and discussed as basis for the preferred alternative selected in Washington State Department of Transportation's (WSDOT) 1993 Final Environmental Impact Statement for Roadside Vegetation Management.

The process of IVM takes into consideration all possible factors surrounding the vegetation problem in order to identify practical solutions. Preferred solutions are site-specific, prevention-oriented, flexible, affordable, and compatible with the Washington State Department of Transportation (WSDOT) objectives for vegetation management. (See **Box 5-G** in Chapter 5 for a explanation of the different types of WSDOT Vegetation Management Program objectives and the relationships among them.) The IVM decision-making process is illustrated in **Figure 1-1.**

In practice, IVM involves the establishment of low-maintenance beneficial vegetation and the suppression of unwanted pest or problem vegetation when *monitoring* indicates *action thresholds* have been reached. The objective is to keep undesirable vegetation levels low enough to prevent unacceptable damage or annoyance. An integration of biological, cultural, manual, mechanical, chemical, and educational tactics are used with an emphasis on *prevention* of problems rather than *reaction* to them. Gradual reduction of both costs and chemical use are central goals in this process. (See "What is a Monitoring Program?" in Chapter 2 and "Determining Action Thresholds" in Chapter 3 for an explanation of terms.)

In IVM programs, treatments are not made according to a fixed schedule. Rather, they are made only when and where monitoring indicates treatments are necessary. Action is taken to prevent the problem created by pest vegetation from growing



The IVM Decision-Making Process

Figure 1-1

large enough to threaten the safety of the traveling public, or cause unacceptable economic, aesthetic, or environmental injury or damage. Problem vegetation that remains below this *action threshold* is considered tolerable. If treatments are needed, they are selected and timed to be:

- Most effective against the vegetation problem
- Most cost effective in the long term
- Least hazardous to humans and the environment
- Least disruptive to natural pest controls or desirable vegetation

When applied appropriately, the IVM process will result in improved management, lower cost, greater ease of maintenance, and lower environmental impacts from maintenance activities.

Box 1-A documents some of the IVM experiences of other states adopting IVM programs for roadside maintenance. The meaning of the term “integrated” is discussed in **Box 1-B.** The components of an IVM program are discussed in Chapters 3 through 6. Chapter 2 provides an example introduction and application of an IVM program within a typical maintenance area. Chapter 7 discusses approaches for successful education and outreach. The following section provides summaries of the IVM decision-making process and the goals of the WSDOT IVM program.

The IVM Decision-Making Process

IVM is a decision-making process. Information from the total roadside management system is used to analyze vegetation problems and implement long-term solutions. This broad overview approach helps vegetation managers answer four key questions:

- If treatment action is needed
- Where treatment activity should take place in the system
- When action should take place
- Which mix of strategies, tactics, and treatments are the best to use

If Treatment Action Is Needed

Instead of taking action at the first sign of a potential problem, the IVM process encourages the manager to ask whether any actions at all are needed. (See Chapter 3 for a discussion of how to determine vegetation *injury levels* and *action thresholds.*)

Example: Until recently, it was WSDOT policy to maintain a “bare earth” zone adjacent to the roadbed due to an assumption that vegetation could directly or indirectly damage the pavement. This was achieved with routine herbicide applications up to 12 feet in width annually along 11,700 shoulder miles of highway (Zone 1 Task Force Study 1993). Closer examination of that assumption revealed that low-growing grasses and forbs (wildflowers, etc.) that do not reproduce from stolons or rhizomes do not damage the roadbed so long as roadside and median *have adequate profile and ditch to provide surface runoff. Under these conditions, it is generally not necessary to remove such vegetation from the shoulder (WSDOT Draft Zone 1 Guidelines 1994).*

Box 1-A. National Trend Toward Roadside IVM: Lower Costs, Improved Management

The IVM concept has been adopted by county and state transportation agencies in a number of states including California, Illinois, Iowa, Wisconsin, Minnesota, and Texas. The concept (popularly known as "Integrated Roadside Vegetation Management," or IRVM) was first applied to county-operated roadsides in Iowa. The primary strategy there is to re-establish the native perennial prairie grasses and wildflowers along roadsides to prevent invasion of weeds and visually enhance the roadsides. This natural method of weed control is supplemented with limited mowing, prescribed burning, and spot-spraying of herbicides to eliminate specific weed problems. Adopted by one county in the early 1980s, the IRVM concept is now fully or partially operational in each of the 90 counties in the state, and the Iowa Department of Transportation has initiated a pilot IRVM program (Daar 1994).

Iowa counties using IRVM report significant reductions in herbicide use from the $70,000 to $80,000 spent per county for broadcast herbicide spray contracts in the 1980s. Prevention of erosion by IRVM programs has also substantially cut costs for ditch clean-outs, which used to total $20,000 to $160,000 annually. Mowing costs are also significantly reduced under IRVM as is the $25,000 to $30,000 formerly budgeted for brush control in each county. Some of these funds are reprogrammed to support vegetation monitoring and replanting activities (Smith 1994). Participating counties report improved management resulting from adoption of IVM techniques and freedom to allocate funds where they are most needed as well as an overall reduction of net costs for maintenance.

Box 1-B. The Meaning of "Integrated"

To integrate means *to combine different elements into an organized, effective whole*. An effective IVM program will:

- Integrate multiple vegetation management tactics with a monitoring and evaluation system
- Integrate understanding of ecological relationships and functional objectives
- Integrate vegetation management with total roadway system management
- Integrate expertise from a variety of sources

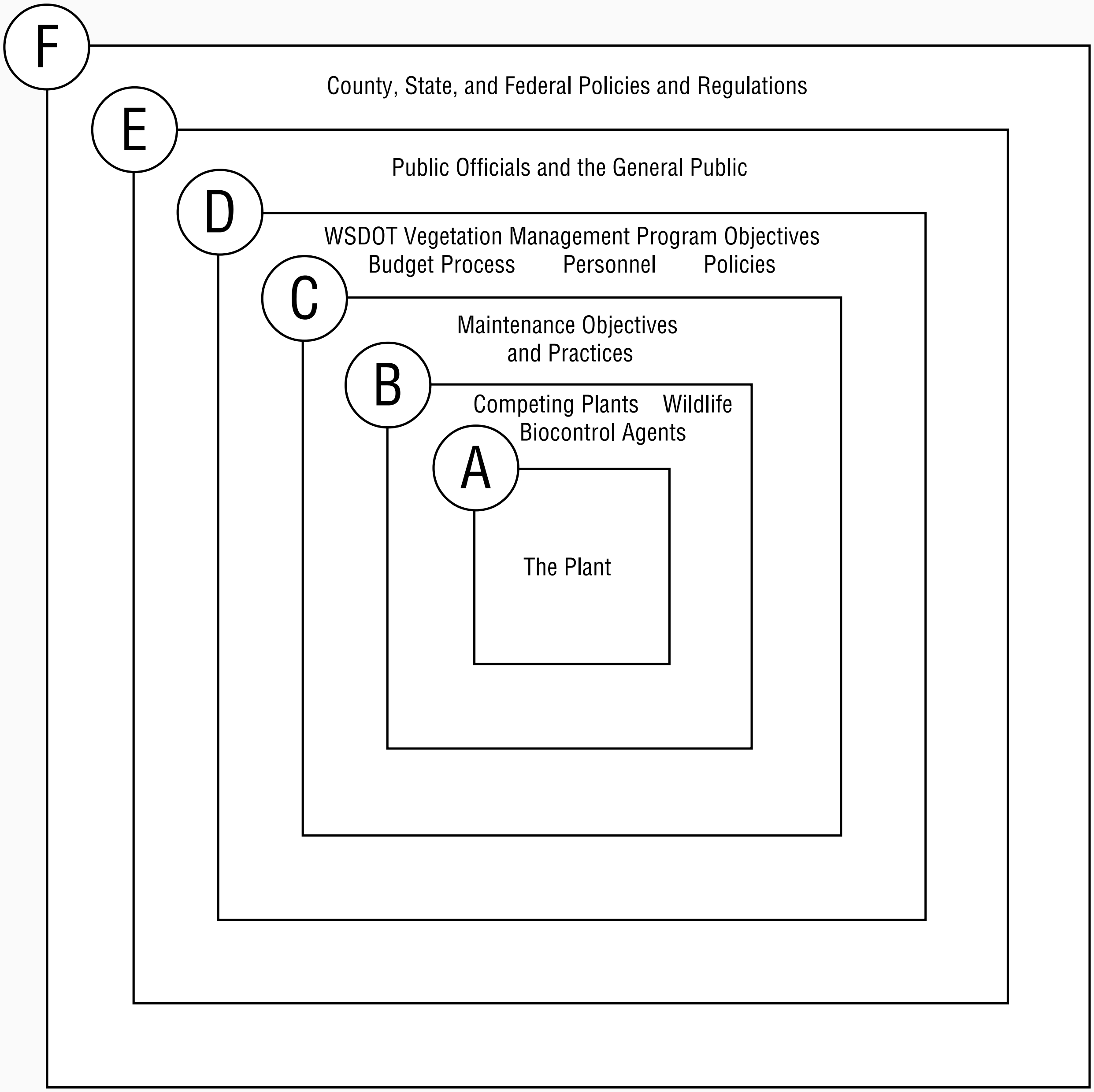
There are several levels of integration in an IVM program. First, a program cannot properly be termed IVM simply because several management strategies (e.g., mechanical, biological, and chemical) or several types of one strategy (such as rotating different herbicides in a chemical control program) are used. A true IVM program organizes a mix of methods through a monitoring and evaluation system; decisions to take action must be based on judgments of the economic, medical, or aesthetic damage the vegetation problem is likely to cause.

Second, in designing IVM programs, the many possible interactions between the vegetation, its natural enemies, other actual or potential problem plants, other maintenance requirements, and WSDOT's overall functional, and environmental objectives for vegetation management must be considered. Implementation must be integrated within this framework to maximize management efficiency and efficacy.

The third meaning of integration is the relationship of vegetation management to the management of the total roadway system — including social, economic, political, ecological, and safety factors that affect vegetation management decisions. These factors must be taken into account when implementing an IVM program. Decisions about vegetation management must be compatible with management of the rest of the system.

The fourth level of integration involves the multi-disciplinary nature of IVM. Depending on the problem at hand, IVM programs must incorporate information from such fields as weed science, entomology, plant pathology, horticulture, landscape architecture, soil science, erosion control, ecology, forestry, arboriculture, agronomy, turf management, chemistry, highway engineering, meteorology, economics, sociology, etc. to effectively solve vegetation problems.

The need to incorporate information from many sources raises the classic problem in systems management: where to draw the boundary of the information gathering efforts in order to make the best decision. **Figure 1-2** depicts boundaries from the narrowest (Level A — the pest problem) to the widest (Level E — Laws and regulations concerning pest control). See "What Information Should Be Collected?" in Chapter 2 for more detail on how to prioritize information gathering.



A highly simplified view of the layers of physical, biological, managerial, institutional, social, and political components surrounding a vegetation management problem.

Where to Draw the Boundary

Figure 1-2

Box 1-B (Continued)

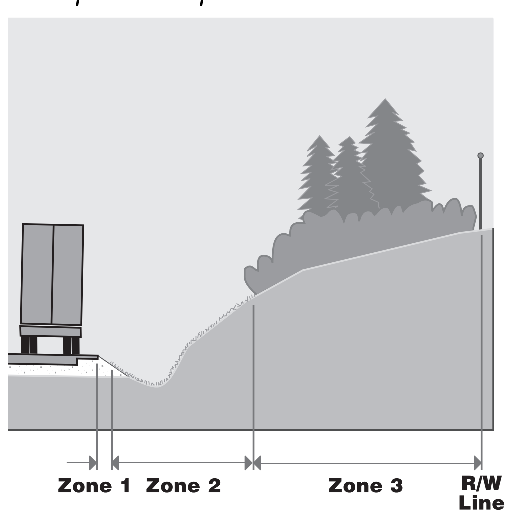
If too much is included, there is too much low-priority information to be processed. Generally speaking, however, it is better to read, question, and observe as much as possible about the system in which the pest problem exists. If the information boundaries are drawn too narrowly, there is a risk that the solution to the vegetation problem will be excluded.

Example: When a weed problem develops along a roadside, common practice is to simply ask which herbicide to apply (Level A). If you draw the boundary a little wider and take into account the physical environment (Level B), you might find that the roadside ditch serves as a drainage for nearby agricultural fields and that weed seeds in drainage water are left on the side of the ditch as water levels recede. If you review management practices that occurred earlier in the season (Level C) and find that the roadside was regraded in early spring but not reseeded, you can assume that the regrading killed established vegetation and left open space for the weeds to colonize. If you draw the boundary even wider to include budget and policy processes (Level D) you may find that there are no policies specifying that reseeding follow regrading operations performed during plant growing seasons. The most effective solution to the problem requires an amendment of policy to mandate reseeding and to allocate funds for that purpose.

Where Treatment Activity Should Take Place in the System

If monitoring data indicates that some action is needed, the IVM process encourages the manager to examine the whole system to determine the best place to modify the situation.

Example: Himalayan blackberry, Rubus discolor*, keeps sprouting in one section of Zone 2 roadside requiring repeated intervention. Higher up the cut bank in Zone 3 is a mature stand of berries which is the source of the Zone 2 problem, though the up-slope blackberries are not in and of themselves cause for concern at that location. Approtriate treatment (i.e. removal of plants followed by a long-term program to encourage competitive desirable vegetation) should be applied to bothe berry stands to avoid re-infestation of Zone 2.*



When Action Should Take Place

There are certain times in the life cycle of a plant or its natural enemies when the pest vegetation is most susceptible to selected treatments. Or, there may be times when applying a treatment is more likely to increase vegetation problems in the long term, rather than reduce them. There may be periods in the overall roadside maintenance calendar when vegetation management is easiest to schedule with other maintenance duties. The IVM process encourages the manger to discover the best timing for treatment actions. (See “Treatment Timing, Rate, and Placement” in Chapter 4.)

Example of timing in the life cycle of the plant: Tansy ragwort, Senecio jacobaea, *fails to produce seed if mowed during early flowering. If mowed earlier in its life cycle, the plant is likely to resurge with new growth capable of ripening seed for growth the following season.*

Example of timing in the life cycle of a natural enemy: The larval stage of a small fly, Urophora affinis, *feeds on knapweed buds before they completely mature (Muller-Scharer and Schroeder 1993). Releasing this predator either before buds have formed on the plant or after flowering would not provide any control because the plant parts attacked by the biocontrol agent would not be present.*

Example of timing in the maintenance system: When switching to IVM, it is essential to integrate the IVM program within the overall roadside management system. For example, ditch cleaning, and roadside grading should be followed soon after by seeding and planting of beneficial vegetation in order to prevent weedy plants from colonizing the disturbed soils.

Which Mix of Strategies, Tactics, and Treatments Are the Best to Use

Four basic principles provide guidance when making decisions on IVM program design:

- Conserve and enhance competitive vegetation and other naturally occurring controls
- Use a multi-tactic approach
- Approach each pest problem with the big picture in mind
- Emphasize prevention and cost reduction

Conserve and Enhance Competitive Vegetation and Other Naturally Occurring Controls

When the competitors and natural enemies of pest vegetation are inadvertently killed by herbicide applications or other maintenance practices, vegetation managers inherit their work. On roadsides and other rights of way, a dense stand of desirable, competitive vegetation is the primary natural enemy of weeds. Other natural enemies of weeds include plant-feeding insects, pathogens, and animals. In many cases, the combined action of all natural enemies present in an area may produce substantial weed control. Even when they are not able to do the complete job, natural enemies are nonetheless providing some help. Competitive stands of desirable vegetation also help exclude or suppress pest bramble, shrub, and tree species. The IVM program should be designed to conserve and enhance desirable vegetation and natural enemies and to avoid damaging them whenever possible. (See "Biological Control" in Chapter 4 for more information on using natural enemies.)

Example: Spotted knapweed, Centaurea maculosa, *is partially controlled by introduced biological control insects* Urophora affinis *and* U. quadrifasciata. *If knapweed is treated with an herbicide late in the growing season, these predatory flies will be harmed (Story et al. 1991). If, however, herbicide is applied in the early spring when knapweed is at the rosette stage of its growth cycle, the biocontrol agents are not affected and will mature to put pressure on the knapweed population that survived the herbicide treatment.*

Example: Dense stands of bracken fern, Pteridum *spp., or sword fern,* Nephrolepsis *spp., can prevent certain tree species such as alders from colonizing the road edge, impeding sight lines and potentially becoming hazardous. The ferns gain a competitive edge over the trees for a number of reasons including the fact that they produce allelopathic toxins that leach into the soil and act as preemergent herbicides against certain other plant species (Gliessman and Muller 1972). By encouraging the ferns to grow in Zones 2 and 3, problems with unwanted trees can be reduced.*

Use a Multi-Tactic Approach

Every source of pest mortality, no matter how small, is a valuable addition to the program. Biological systems are so complex that a single tactic, such as the application of an herbicide, may not solve the problem for long. As many tactics as possible should be combined to manage the pest problem, with herbicides as a backup when needed. (See "Vegetation Management: Strategies, Tactics, and Treatments" in Chapter 4.)

Example: A program of Scotch broom, Cytisus scoparius, *suppression could combine direct control of problem plants using properly timed manual or mechanical removal, burning, or herbicides followed by deep mulching (4 to 6 inches or more) of the exposed soil with chipped plant debris. The experiences of horticulturists managing Scotch broom in California indicate that a deep mulch will suppress Scotch broom seeds, preventing them from obtaining the sunlight needed to germinate until such time as replacement plantings of desired vegetation have become established.*

Approach Each Vegetation Problem With the Big Picture in Mind

Each vegetation problem must be considered within the framework of the larger system in which it has arisen. Textbooks and manuals commonly treat pest vegetation species one by one. However, in the "real world" setting of a roadside, pest vegetation species occur several at a time or in a sequence in which management of one influences the others. In addition, vegetation problems are influenced by other human activities such as clearing, mowing, ditch clearing, revegetation projects, etc., as well as by adjacent landowners, traffic, and personal bias. Vegetation management decisions must take into consideration these other factors in order to be practical and effective (also see **Box 1-C**).

Example: Knapweed, Centaurea *spp., invasion is facilitated by human activity. Vehicles passing through knapweed-infested areas pick up seeds. These seeds are then dropped along roadsides which have been recently regraded or disturbed by* *herbicide applications or mowing activities, providing habitat for knapweed seedlings. The natural enemies of knapweed are not transported with the seeds. A "big picture" approach to knapweed control on roadsides would recognize these contributing factors and include a mix of strategies to address them. These could include a policy of avoiding creating bare or disturbed soils whenever feasible, revegetating roadsides with desirable but competitive plant species, releasing biocontrol agents, creating a public education program, and direct intervention with mechanical and chemical treatments.*

Box 1-C. Keeping the "Big Picture" in Mind: The Components of an Ecosystem

Vegetation is one component of a larger roadside ecosystem. To a scientist, an ecosystem is usually thought of as containing all the living and nonliving components of the system where a vegetation problem is occurring. Nonliving components include sun, air, soil, and water. Living components include plants, herbivores (animals that feed on plants), carnivores (animals that feed on animals), detritivores (organisms that break down plant and animal material to smaller organic compounds), and decomposers (organisms that break down organic matter to nutrients and other constituents).

From the standpoint of the designer and manager of an IVM program, it is helpful to include another category — social/political components. These can include coworkers, adjacent land owners, public agencies or institutions, professional associations and community groups, the general public, and the political and legal constraints of the society at large. All of these act to shape management goals and practices within the maintenance system.

The many components of this ecosystem may be thought of as a series of systems, each having impact on the other and all potentially impacted by a pest management program. The components are illustrated in the figure in **Box 1-B**.

When designing and implementing an IVM program, it is important to consider all of these components. Of course, it is impossible to consider every aspect of each. The manager must choose which aspects of the system are most important to include in the decision making process. (See "What Information Should Be Collected?" in Chapter 2.)

Emphasize Prevention and Cost Reduction

IVM programs seek to identify and reduce or eliminate the basic causes of vegetation problems. This approach differs from conventional weed control programs that focus primarily on routine treatment of symptoms (i.e., the weeds alone) with broadcast applications of herbicides, mowing, or brushing. The conventional approach requires repetitive treatments that produce short-term results and in the long run often intensify maintenance problems. This occurs when weed control activities create bare soil vulnerable to erosion and invasion by weeds, or when they have a negative effect on the health of desirable vegetation.

With IVM, the objective is to replace unstable vegetation that is vulnerable to invasion by weedy plants with stable beneficial vegetation that is compatible with functional zone objectives and can resist invasion by undesirable plant species over the long term. In this approach, chemical controls are generally only applied in the early transition stages to achieve initial control of a severe weed problem. Once the beneficial replacement vegetation has become established, vegetation management needs generally drop to a low level and can be handled primarily with nonchemical methods.

IVM and the Roadside Management Zones

Roadsides along WSDOT highways are divided into three zones that help classify the priority and types of maintenance activities performed in highway rights-of-way. Not all zones occur on every section of highway. **Figure 1-3** shows where roadside management zones are typically located and the functional objectives for each zone.

The proximity of these zones to the traveled roadway and the presence of abutting property owners dictate the objectives for each zone. The most intensive vegetation management area is Zone 1, which is managed to be free of vegetation. This zone is not always required. Zone 2 is managed primarily for visibility, shading, and drainage control, while Zone 3 is often left natural or planted, and managed only for purposes consistent with visibility, danger trees, or noxious weed control. (See “Vegetation Management: Strategies, Tactics, and Treatments” in Chapter 4.)

By promoting, planting and caring for desirable native and adapted plants on the roadside, long-term maintenance costs will decrease because weed habitat will be substantially reduced. An example of this approach is WSDOT’s recent decision to reduce the size of Zone 1 to a width of 0 to 2 feet and to modify the former “bare earth” policy in order to permit low-growing, nonstolon or rhizome-producing vegetation to grow in the former Zone 1 so long as surface water flow is not impeded.

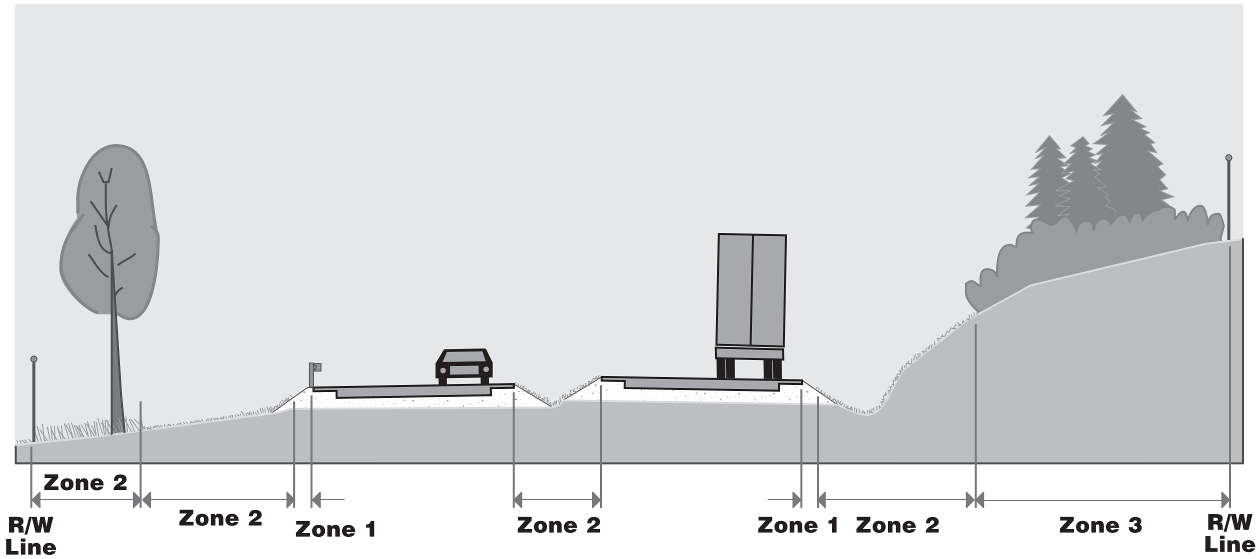
Likewise, by using an IVM approach in Zone 3, many native or adapted plant communities can be managed to require very little attention. Therefore, Zone 3 should be allowed to extend to its maximum width in all right of way situations so long as it is not in conflict with the overall maintenance objectives.

Role of IVM in WSDOT

The use of an IVM approach for roadside vegetation management fits well with the vision, mission, and stretch goals of WSDOT. Ultimately, a successful IVM program will allow state highway maintenance forces to better achieve the identified maintenance objectives:

- Provide safe, reliable transportation
- Maintain investment, lower life cycle costs
- Support commerce and economic viability
- Comply with legal mandates

Roadside Management Zones



Functional Zone Objectives

Zone 1: Vegetation Free Zone

(0 feet to 2 feet from pavement or as necessary)

- Provide for surface drainage
- Reduce fire potential
- Provide for visibility and maintenance of roadside hardware
- Prevent pavement breakup by invasive plants
- Provide sight distance for passing, stopping, and at intersections
- Prevent the buildup of wind blown debris and winter sand at the pavement edge

Zone 2: Operation Zone

(from Zone 1 to meet operational needs)

- Maintain vehicle recovery area
- Provide sight distance for passing, stopping, and at intersections
- Maintain hydraulic capacity of ditches
- Eliminate hazard trees (and trees shading the highway)
- Control weeds
- Prevent erosion
- Provide wildlife habitat where compatible with roadway traffic
- Accommodate underground utilities
- Enhance visual quality

Zone 3: Transition Zone

(from Zone 2 to R/W line)

- Promote self sustaining plant communities
- Blend and/or screen adjacent surroundings to meet the goals and objectives of the Roadside Classification Plan
- Control weeds
- Prevent erosion
- Maintain and enhance visual quality
- Preserve wetlands and wildlife habitat
- Accommodate utilities
- Preserve and conserve native plants and wildflowers

Roadside Management Zones

Figure 1-3

- Be a responsible member of the community
- Be environmentally responsible
- Contribute to a positive appearance

This type of an approach to vegetation management also ties in with TQM and each Critical Success Factor and Stretch Goal of the department's Q2000 program. The use of IVM will improve the quality of the roadside maintenance program because:

- The process relies heavily on continuing education and the day-to-day observations and judgments of the maintenance technicians and supervisors
- The documented cycle of monitoring, evaluation, and adjustment of tactics will result in measurable improvement over time
- Better records and a consistent decision-making process will enhance communication of WSDOT's program to the public, the legislature, and throughout WSDOT's internal divisions
- The process recognizes the importance of making decisions based on accurate information and an awareness of context within the big picture

As with the overall WSDOT quality program, the IVM program will be implemented slowly over a number of years. Each area maintenance office has a unique set of responsibilities and resources as well as individual organizational structure and personality. The Field Operations Support Service Center Maintenance Office will work to provide useful tools and reference information to the regions and the individual areas as needed. Additional information and review of material in this manual will be presented annually at the spring training sessions and the Roadside Maintenance Division of the Maintenance Office will be available to conduct area specific program review sessions in individual areas as needed.

There will also be a need for maintenance to utilize other existing resources within the department for consultation and development of IVM programs. The regional landscape architects and environmentalists, the departmental horticulturist, as well as personnel from other maintenance areas all have extensive knowledge of vegetative behavior and treatment options.

3:P:DP/IVM

IVM Begins With the Maintenance Areas

Integrated Vegetation Management (IVM) is nothing more than an application of quality management principles. A problem or process is observed, evaluated, and improved upon (if possible). The only place this can happen is in the individual maintenance areas, and within the natural work groups of the section crews. While this manual contains useful tools and ideas, it is up to the individual maintenance areas and section crews to adapt them and develop their own ways of putting IVM into practice.

It is also up to the individual areas to determine where to begin using IVM and how much to initially invest. Without dedicated funding for IVM, it will only be possible to address small areas in the first years. However, the justification for future funding of the vegetation management program will be based on the documented successful use of IVM to achieve optimal roadside conditions. By demonstrating with small examples throughout the state, the Washington State Department of Transportation (WSDOT) can show the potential benefit to interested customers and begin to build credibility for the future of the roadside vegetation management program.

This chapter describes, in general terms, the recommended process for beginning to use IVM within a typical WSDOT maintenance area and then expand its use over time. The material in this chapter is presented as an outline, with reference to other sections for detailed information, examples, and descriptions.

Selecting a Series of Initial Locations

With limited funding available to roadside maintenance, the only way to begin is to start with a small and manageable problem area. In order to determine and prioritize the problem areas within the overall maintenance area, the crews should meet and discuss overall priorities and maintenance objectives for the roadside zones throughout their area. The next step is to determine where there are locations most in conflict with the objectives and then begin implementation of IVM in those most critical or problematic locations — even one location can serve as a starting point. The site or sites selected for initial implementation may contain one or more of the following conditions:

- Contains an infestation of problem vegetation which far exceeds the acceptable injury level
- Contains a wide cross-section of typical and reoccurring vegetation management problems
- Contains a new, unique, and/or extensive infestation of noxious weeds
- Contains sensitive water quality areas
- Is a highly visible or visually important part of the surrounding community
- Generates significant neighbor or general public complaints

- Ties in with other planning efforts currently underway

By focusing on a specific area for several years and applying some up-front investment, we can reduce the long-term maintenance requirements of that area and then turn to focus on the next most important problem area.

The objective of this approach is to:

- Gain experience applying IVM philosophy and methods to roadside vegetation in a gradual and manageable way
- Test site-specific methods for achieving vegetation management goals using long term planning, and to practice documenting results
- Gradually integrate IVM practices within overall maintenance operations as the methods and concepts are proven over time
- Begin making incremental reductions in the long-term life cycle costs of vegetation management while using environmentally sound practices

After two to three years, the initial focus areas will have begun to show benefits of a concentrated IVM effort, and another set of areas can be selected depending on the perceived benefits and available resources. The experience gained through early efforts will be used to help evaluate the long-term economic consequences of applying preventative vegetation management approaches system-wide.

Approaching the IVM Start-up Phase

An important goal of the start-up period is to begin integrating IVM activities into the existing maintenance system. It will be up to area superintendents, supervisors, and lead technicians to determine how best to distribute IVM responsibilities and work assignments. The objective is to build upon the skills and acquired knowledge of maintenance personnel to promote IVM implementation within WSDOT by building.

The IVM approach is twofold. It is designed to reduce the amount of vegetation removal required annually and to increase the amount of stable, self-maintaining vegetation present on the roadside. This calls for both an adjustment in management philosophy and an expansion of horticultural skills and knowledge on the part of maintenance personnel. Appropriate technical support, incentives, and recognition of individual achievement will be required to encourage the transition.

During the IVM start-up phase, it is essential that from the beginning realistic objectives be established between supervisors, lead technicians, and maintenance crews as part of the IVM program development and operation. Everyone involved needs to understand the components of the IVM program so they can provide suggestions for ways to incorporate the program elements into current operations. The ongoing IVM program will not work as a parallel process to existing maintenance activities; it must become an integral part of the overall maintenance system.

Example: Maintenance crews are already casually monitoring and taking mental notes on elements of the roadside while traveling to and from job sites. With minor adjustments and minimal time investment, documented vegetation monitoring and data collection could be accomplished during normal daily travel. Simply *recording the date and place of observations along with the observations themselves will provide the structured information needed to use the observations in a monitoring and evaluation program.*

Implementing an IVM Start-up Program

The process of applying IVM to a maintenance area can be divided into six steps:

1. Identify the Vegetation Management Objectives
2. Develop and Implement a Monitoring Program
3. Determine Injury Levels and Action Thresholds
4. Apply Least Disruptive Control Tactics and Effective Revegetation Methods
5. Evaluate Effectiveness of the Treatments and Adjust Accordingly
6. Continue Monitoring and Evaluating

Examples of these steps are described below for situations occurring in typical roadside situations. The relationship of these steps to each other is shown in **Figure 1-1,** provided in Chapter 1.

1. Identify the Vegetation Management Objectives

As discussed earlier in this chapter, the first step in applying IVM is to review the roadside objectives and to discuss the condition of roadsides throughout the entire maintenance area or section in relation to those objectives. This process should be used to determine the overall priorities in terms of required vegetation management activities and locations of greatest need. Once the initial focus areas have been selected, the objectives for these areas should be documented as part of efforts to record baseline information for these areas. Three levels of maintenance objectives are discussed below. Each level should be considered in relation to roadsides throughout the maintenance area.

Overall Maintenance Objectives

The most important requirements of any roadside (or roadway) relate to the safe operation of the highway and the preservation of the infrastructure; others relate to being a responsible member of the community, environmental responsibilities, and contributing to a positive appearance. These requirements provide the basic reasons *why* highway maintenance is necessary and they can be defined as the overall highway maintenance objectives. They are also relative to each other in terms of importance. In order to determine the priorities of specific roadside maintenance activities, the activities must be analyzed in relation to their contribution to the most critical needs or objectives. One way to determine priorities is described in **Box 2-A**

Box 2-A. A Method for Establishing Roadside Maintenance Priorities

In the fall of 1995, a team of WSDOT maintenance employees and landscape architects met to study the issue of roadside maintenance priorities. Using brainstorming techniques, the group came up with a series of primary maintenance objectives similar to those mentioned above. The objectives were then assigned relative numeric weights to show their importance in relation to one another. A matrix was then generated using the maintenance objectives along one axis and a list of roadside maintenance activities along the other axis.

The team then carefully rated each activity by its contribution to each of the maintenance objectives. The activities were rated as being either critical, significant, contributing, or non-effecting to the accomplishment of the individual objectives. The activity ratings were also given a numeric weight, limited to a maximum of 15 percent of the total number of activities being critical, and a maximum of 30 percent being significant. When the activity ratings were multiplied by the respective value of the objectives, a prioritized list of activities was generated. The finished product of this study is included as **Figure 2-1.**

Despite some skepticism during this exercise, once the final list was generated, the team members agreed that for the most part activities were ranked in the correct order. This proved a valuable exercise for those involved and should also prove useful to any maintenance office or crew in the analysis of individual vegetation management programs.

WHAT? Maintenance Activities	Why? (Program Goals)						
	Provide safe, reliable trans-portation	Maintain the investment at the lowest life-cycle cost	Support commerce and economic viability	Address legal mandates	Be a responsible member of the community	Be environ-mentally responsible	Contribute to a positive appearance
Critical Activities							
Repair major slide and erosion damage	critical	critical	critical	critical	critical	critical	significant
Maintenance of cross culverts	critical	critical	critical	critical	significant	significant	significant
Control noxious weeds	contributes	critical	critical	critical	critical	critical	contributes
Control of brush and grass in high risk areas	critical	significant	significant	critical	critical	critical	critical
Eliminate danger trees	critical	significant	significant	critical	critical	contributes	contributes
Remove road kill hazards	critical	none	critical	contributes	significant	significant	critical
Repair or clean ditches & side culverts >50% full	significant	critical	significant	significant	critical	significant	significant
Promote low maintenance plant communities	significant	critical	significant	none	significant	critical	critical
Irrigation operation & repair for plant survival	none	critical	significant	contributes	significant	contributes	critical
Repair fences for safety reasons	significant	significant	contributes	significant	critical	contributes	significant
Dispose of road kill	significant	none	significant	significant	significant	critical	significant
Significant Activities							
Control nuisance weeds	contributes	significant	significant	significant	significant	significant	significant
Weed & brush control in formal landscaping	contributes	significant	significant	contributes	significant	contributes	critical
Control of brush and grass in moderate risk areas	significant	significant	contributes	contributes	contributes	significant	significant
Repair & maintenance of trails, viewpoints and Park & Ride lots	contributes	significant	significant	significant	contributes	contributes	significant
Repair minor slope and erosion damage	contributes	significant	contributes	contributes	significant	significant	contributes
Litter bag pick-up and disposal	contributes	none	contributes	contributes	significant	significant	critical
Turf care	none	significant	contributes	significant	contributes	contributes	significant
Soil enhancement in landscaped areas	none	significant	significant	none	contributes	significant	contributes
Contributing Activities							
Irrigation operation & repair in established plantings	none	significant	contributes	contributes	contributes	contributes	contributes
Repair fences for other reasons	contributes	contributes	none	contributes	significant	none	significant
Repair or clean ditches & culverts < 50%	contributes	contributes	contributes	contributes	contributes	contributes	contributes
Misc. litter pick-up	contributes	none	contributes	contributes	contributes	contributes	significant
Adopt-A-Highway program administration	none	none	none	significant	contributes	contributes	critical
Control of brush and grass in low risk areas (including for aesthetics)	contributes	none	none	none	contributes	contributes	contributes

Table 2-1

Roadside Maintenance Priority MatrixM2 Program Categories Group 2 and 3

Functional Zone Objectives

The overall maintenance objectives can then be related to all major maintenance work groups: Roadway, Snow and Ice, Roadside, etc. Roadside maintenance objectives are classified in relation to one of three management zones paralleling the roadway. Roadside management zones are discussed in Chapter 1 on page 1-11 and illustrated in Figure 1-3 on page 1-12.

Roadside management zones also play a part in the setting of vegetation management priorities. Zones 1 and 2 contribute significantly to the safety and operation of the highway facility and generally require more attention. Zone 3, when present, contributes more to the environmental and visual aspects of the highway right of way. Zone 1, when needed, is managed to be free of vegetation Zone 2 is managed for site distance, errant vehicle recovery, and drainage. Zone 3 is managed only for purposes such as removal of danger trees, and views or screening in relation to the surrounding landscape and the presence of neighbors. Other vegetation management considerations are present through all three zones, such as erosion control and noxious weed control. (Many invasive nonnative plants are listed as “noxious” weeds by the Washington State Noxious Weed Control Board which mandates treatment of many of these species. This subject is discussed further in Chapter 5.)

Aside from the functional objectives for each zone, it is important to consider the actual width necessary for Zone 1 (and if it is necessary at all), and the necessary width of Zone 2. Because these zones require significantly more energy and resources to manage, they should be kept to the minimum practical width. Zone 3, if managed using an IVM approach, can be established to require only occasional treatment.

Long-Term Vegetation Management Objectives

Long-term vegetation management objectives play an important role in determining the methods used by maintenance crews to fulfill functional zone objectives for specific sites. The primary vegetation management objective for Zones 2 and 3 in all sites is to establish stable, desirable, low-maintenance vegetation that meets the overall maintenance objectives, the functional zone objectives, and is compatible with the desired landscape character.

Site-specific vegetation management objectives may change to fit public demands, variations in conditions between sites, or advances in knowledge and available equipment. Objectives must be distinguished from methods (strategies, tactics, and treatments). The objective is a goal and focuses on the end result to address customer needs. Methods are means to achieve the objective.

Example: Zone 2 in a given area is mowed two to three times a year to keep weeds from going to seed, control alder and conifer seedlings, and maintain an aesthetically pleasing appearance. Over the years, Zone 2 has crept out to an average width of 100 feet along this fairly uniform stretch of road.

> ***Maintenance Objectives:*** *Provide safe sight distance around curves, an adequate vehicle recovery zone, and contribute to a positive appearance,*

Vegetation Management Objective: *Establish and maintain a stable and fairly uniform grass stand with the lowest level cycle of treatment. Bring Zone 3 to within 30 feet of the roadway edge.*

Method: *In Zones 2 and 3, use timed mowing and spot-treatment with herbicide if needed during the first year to reduce weeds to an acceptable level. In Zone 3, plant a mix of vine maple and salmon berry in a 20 feet wide band beginning 30 feet from the edge of the road and a mix of Douglas fir and western red cedar to fill in the remaining area to the previous Zone 3 edge. Fertilize and lime as needed. If needed fertilize and over-seed Zone 2 with grass. Begin an annual ongoing program of mowing one swath next to the road twice a year and mow the entire Zone 2 area once every three years. Monitor for weeds and spot-treat with herbicide if necessary.*

There may be many possible vegetation management objectives that will fulfill overall and functional objectives. Vegetation management objectives will be site-specific, may change from year to year, and may be influenced by shifts in budget allocation and changes in public and governmental expectations about roadside management.

Changes in technology, techniques, or understanding of management situations may suggest changes in vegetation management objectives. For example, recent research suggests that nonstoloniferous vegetation on roadway shoulders does not harm pavement. This has lead to a reevaluation of the vegetation management objective of keeping Zone 1 free of vegetation. Balancing a wide variety of factors and determining optimal vegetation management objectives will always be the greatest challenge to successful management of roadside vegetation. Applying IVM concepts and record-keeping tools will help maintenance plan and account for the answer to this challenge. The development of the monitoring program flows from careful consideration of vegetation management goals.

2. Develop and Implement a Monitoring Program

This subject is discussed in detail in Chapter 3 of this manual. It will be useful to also review the information in Chapter 3 when designing a monitoring program. When beginning to use IVM in selected focus areas, monitoring may take a slightly different form than when applied throughout the area in an ongoing program. Monitoring techniques can be developed and refined during the first years of IVM implementation using the initial focus areas as test cases. The program can then be expanded within each maintenance area to the degree that matches its usefulness, and ultimately a statewide monitoring system may evolve around a computerized database.

A vegetation monitoring program contains two general types of information. The first is information about site history, including relevant details about construction**;** pre-construction vegetation and wildlife; historic or ongoing maintenance activities and impacts; adjacent land use; any documented corridor management plans, etc. The second is information about current site conditions and how they are changing over time.

Types of Historic and Primary Information to Collect

A successful monitoring program must be based on a relatively complete understanding of the conditions and management of the roadside to date. Obtaining this understanding can only be accomplished by gathering information about the history of a site as well as about current conditions. The management history and baseline information relevant to a site must be collected and organized. A sample Baseline Site Information form is included in **Appendix 1.** This (and other sample forms) is also available as a computer application. Contact the Field Operations Support Roadside Branch for information. As a start, the paper form can serve as an excellent "check list" for initial efforts at gathering baseline information when developing a monitoring program.

Baseline information can be gathered through roadside inspections, evaluation of existing records of management histories, and discussions between crew members or in crew meetings. Information on prior methods, even if no longer used, should be included since it is always useful to be aware of what did or did not work in the past.

The information collection process should also gather suggestions from maintenance personnel for changes in roadside design to reduce future need for vegetation management. Design changes could be incorporated into future upgrades of existing roads or in new roads.

Example: By paving the shoulder an additional 2 feet down the slope toward the ditch, the need to maintain a vegetation free zone is eliminated and grass can be grown up to the edge of pavement without inhibiting surface drainage.

Site baselines can be stored in files in the supervisors office or, if possible, the computer application can be used to record information as part of the system-wide database. However they are filed, the baseline information needs to be accessible and easily referenced by monitoring personnel for planning maintenance activities or interpreting monitoring data.

How to Prepare for Ongoing Monitoring Activities

Once the initial focus area(s) within the maintenance area have been identified and mapped, the next step is to design and create a record-keeping system for ongoing monitoring activities. This record-keeping system stores and organizes annual monitoring data for specific sites. The form and procedures used should be tested and refined during the IVM start-up period. Sample monitoring forms are included in **Appendix 1.** The exact layout can be tailored a number of ways but should include spaces for recording at least the following information:

- The date, exact location, time spent, and the name of the person monitoring
- Which species of problem and beneficial plants or other management factors are present
- Cover or density of the plant species or number of plants
- Current action threshold for each species and check off box to indicate if the action threshold has been reached
- Miscellaneous notes on observations of the site

- Space for making recommendations about effective treatments
- Space for diagrams, sketches, or photos

The importance of a clear understanding of vegetation management objectives and their connection to maintenance activities makes it necessary to specify management objectives in writing when working in an area. Careful consideration of management objectives will reveal new factors which will require monitoring.

Example: WSDOT has a functional objective of creating and maintaining stable vegetation complexes along roadsides in an effort to reduce long-term costs of roadside vegetation management. This suggests that the health of beneficial vegetation should be monitored. One of the best measures of this is bare ground area. A trend of increasing bare ground area indicates that beneficial vegetation is thinning and noxious weeds or other problem plants may soon have the opportunity to invade and establish. For this reason, injury levels and action thresholds for bare ground area should be set and bare ground area should be monitored regularly.

Example: Many highways in urban and suburban locations have a high percentage of roadside that abuts residential areas. In addition to the functional objectives of maintaining safety, visibility, and drainage, maintaining good neighbor relations is one of the primary goals for these areas. Monitoring notes should include information on encounters with neighbors.

It may be useful to specify management goals for each roadside zone separately at such sites. This will allow lead technicians to identify problems efficiently. A plant species that is a problem in one zone may not be in another.

Example: Horsetail, Equisetum *spp., can damage pavement and other structures if growing in close proximity, but may be tolerable elsewhere, such as in a grassy area in Zone 3. Cottonwood and alder may block signs, shade the roadside, and present a tree-fall hazard if growing in Zone 2 but may be tolerable up to a certain size in Zone 3. Using a written record-keeping system to keep these distinctions clear will help optimize management choices made at all levels in the organization.*

Included later in this chapter are example forms structured to track the link between management goals and management activities. In other words, all records of work activity should include a brief description of why the activity took place in terms of which management goals were addressed by the activity.

The Importance of Good Record-Keeping

Good record-keeping is critical to maintaining quality and integrity in a time of rapidly changing public needs and concerns and expanding environmental regulation. Accurate and detailed records compiled through monitoring will help WSDOT justify its management decisions and document improvements in the quality and cost effectiveness of management efforts.

Good records are also vital to improving management techniques. Finding effective new practices, changing or eliminating ineffective old ones, controlling costs, and improving quality of management can only be achieved if records of management efforts and their results are diligently maintained. Time records could be adapted to include documentation of monitoring activities, vegetation establishment and restoration, and other components of the IVM program. These could be fed into the accounting system for integration into statewide cost accounting and tracking systems.

Properly Timed Monitoring

There are many factors to consider when allocating resources to monitoring. It may be prudent to create a list of situations where monitoring is of little value. For example, all annual and many perennial weeds have a period of decline or dormancy. Monitoring an area for these problem plants when they are declining, dead, or dormant does not provide useful information. Thus, knowledge of the life cycle of problem plants, gathered from experience or technical sources, can help in effective allocation of monitoring resources. Also, areas which have been host to a stable community of desirable plants for several years may need very little maintenance and should not be the focal point of extensive monitoring efforts. Monitoring activities should be planned to occur during periods when problem-causing plants are growing rapidly, are easy to distinguish from other vegetation, and are vulnerable to the most effective treatments. Refer to Chapter 3 for more information on focusing monitoring efforts and planning monitoring activities.

3. Determine Injury Levels and Action Thresholds

The next step in the process is to set injury levels and action thresholds for target vegetation. (For a full discussion of this concept, see Chapter 4, “Deciding When and Where to Apply Treatments.”) This concept can be understood by posing two related questions:

> “How many of these plants can be tolerated at this location without causing sufficient problems to warrant the time and expense to suppress or remove them?” (The answer to the question constitutes the injury level.)
>
> “At what point is a control measure needed to prevent the number of plants from reaching or exceeding the injury level?” (The answer to that question constitutes the action threshold.)

The objective is to become familiar enough with the behavior of the target plants that action is only taken when needed to prevent unacceptable damage from occurring. Using this approach will help reduce any unnecessary routine weed control, and is the key to reducing long-term maintenance costs.

Ideally, both injury levels and action thresholds should be determined by matching quantitative data on weed cover or density at a site with economic data concerning the costs of control vs. the damage sustained if no control is attempted. Initially, injury levels and action thresholds must be set somewhat more subjectively on the basis of lead technician and supervisor experience.

Example: Some problem plants are slow growers, others spread quickly. Common mullein, Verbascum thapsus, *tends to grow and spread slowly. Managers should have a higher tolerance for this plant when it first shows up since it is unlikely to develop into a serious problem quickly. Action thresholds will be close to the injury level. A patch of Canada thistle,* Cirsium arvense, *however, can expand up to sixteen feet in a single season. Managers should have a low tolerance for this plant, and should set action thresholds well below injury levels, since the plant can quickly grow from an economically insignificant patch to a major problem.*

Initial injury levels and action thresholds will be refined in subsequent years using the experience gained and information collected through monitoring.

Injury levels and action thresholds will vary according to plant species, management goals, and zone. A species which is a significant problem at one site may not be problematic at another location.

Example: Since enhancing wildlife and native plant habitat values are among the key management objectives for wetland mitigation sites, there should be a low tolerance for invasive, nonnative species in any of the zones. In this case, both Himalayan blackberry, Rubus discolor, *and Scotch broom,* Cytisus scoparius, *are considered threats because they tend to out-compete native vegetation, reducing plant diversity on the site. However, excessive intervention or disturbance by maintenance workers could also reduce the site's attractiveness to wildlife. The supervisor must decide an appropriate balance between limiting invading species and minimizing maintenance intervention.*

Injury levels and action thresholds may also be influenced by indirect effects of vegetation.

Example: For management of horsetail, Equisetum *spp., monitoring may reveal that repeated problems with horsetail in some areas are associated with spread of horsetail from Zone 3 into Zone 1. Data on density or cover of horsetail in one site can be compared with data from similar sites where horsetail grows in Zone 3 but rarely spreads to Zone 1. If it is assumed that the horsetail population on the site with no spreading problem is below the action threshold, then that data can be used to help set an action threshold for horsetail in Zone 3 at the original site. Areas with horsetail populations above this level should be targeted for control and replanting activities in order to reduce future need for horsetail control in Zone 1.*

Need for Education and Outreach

The ideas of vegetation injury levels and action thresholds are among the newest concepts WSDOT will be incorporating into its vegetation management activities and will require the most explanation and communication.

There will need to be an effort to educate all members of the WSDOT staff who affect roadside vegetation about the rationale and benefits to be gained from putting the IVM approach into practice. This includes *all* maintenance employees, construction offices, engineers and designers, as well as roadside maintenance crews, pesticide applicators, and others already directly involved in vegetation management. Public education and outreach will also be needed. This is especially true for the attempt to establish permanent, low-maintenance vegetation. Some people will praise the new methods, others will criticize them. Some of the public will miss the "lawn-like" look of closely mown grasses where mowing height has been raised to prevent weed invasion. Others will enjoy the "meadow-like" look of the wildflowers that spring up under higher-mowing regimes.

An asset of the IVM approach, however, is its flexibility when confronted with conflicting goals. In locations where the "neat and tidy" mowed look is required but does not prevent weeds from establishing, the IVM approach would be to move away from grass altogether and substitute a planting of low-growing permanent groundcover suited to the site.

Chapter 7, "Education and Outreach," discusses the topic of education in more detail.

Implement Ongoing Monitoring Activities

Once a monitoring program has been designed, forms for data collection prepared, and preliminary injury levels and action thresholds determined from prior experience of maintenance crews and current site observations, the next step is to begin ongoing monitoring activities. The timing, frequency, personnel, and sampling methods involved must be decided.

Timing

Monitoring should be timed to coincide with periods when vegetation is likely to have significant impacts on management objectives for a site. For example, each of the noxious weed species will have an active growth season and, within that season, a window of vulnerability when it is easily detected and/or susceptible to cost-effective control treatments. Beneficial plants will have a period when they are most easily established or when they may need management assistance to persist.

Example: At a given site, management efforts have been focused on keeping trees clear of structures and controlling noxious weeds. Monitoring efforts on this site should be timed to reveal the presence and abundance of noxious weeds and the degree of tree encroachment on structures.

Example: In some of the roadside ornamental plantings, Himalayan blackberry, Rubus discolor*, and Scotch broom,* Cytisus scoparius*, infestations have presented a continuing problem. Recent control and revegetation efforts have succeeded in replacing this vegetation with desirable grasses. Monitoring on this site should be timed to catch both weedy species early in their growth cycle. Monitoring periods should also overlap with the rapid growth phase of the grasses so that it will be possible to evaluate bare ground area and the need, if any, to mow.*

Wherever possible, the timing of monitoring should be set to also coincide with other maintenance activities in or near the monitoring site such as pavement and structure repair. Linking monitoring with other activities will allow efficient use of staff resources. Also, visits to focus areas which are near one another can be linked to coincide so that several areas can be monitored in one session.

Frequency

Monitoring must be frequent enough to catch problems before they get out of hand and before critical windows for effective treatment close. During the spring, when both broadleaf weeds and grasses are most active, monitoring should be frequent enough to determine when action thresholds are reached (e.g., when noxious weeds have reached the bud stage and should be mowed to prevent seed set). Monitoring should be most frequent in areas of critical concern such as roadside segments where new management techniques are being applied. The important thing is to monitor a site only as frequently as necessary to obtain sufficient information to time the right treatment at the right time to achieve the management objective.

Personnel

Monitoring should be conducted by the person who normally visits or passes by on a regular basis. This may vary from site to site. Special sites, such as a new wetland mitigation area, may be most frequently visited by the supervisor. For most areas, either lead technicians or maintenance technicians would be most appropriate to conduct the monitoring.

Monitoring forms should be filled out completely at each site visit and copies retained by both the supervisor and the lead technician for the area.

Monitoring Methods

Appendices 2, 3, 4, and 5, provide numerous examples of monitoring methods and their application. The method can be tailored to fit the needs of the area.

Example: To monitor for establishment of an English ivy, Hedera helix, *bed in a landscape planting, accurate data collection could be accomplished by visual estimation of percent cover, percent bare area, and/or total area covered.,*

Example: A "truck transect" could be used to monitor for noxious weed populations in most cases. (See "Vehicle Window Frame Sampling" in Appendix 5.)

Need for Staff Training

Monitoring will only be effective if it is done properly. It will be important to provide training opportunities for personnel who will be involved in monitoring activities. The rationale for monitoring and the details of how to apply sampling and record-keeping techniques must be understood by the staff members who will be gathering data. This manual will provide much of the material needed for training efforts. See Chapter 7, "Education and Outreach," for more detail.

Importance of Repeated Monitoring

Management efforts will be most effective if applied only as needed, not before or after. Repeated monitoring allows problems to be detected before they become difficult to control and prevents costly and potentially ineffective treatments applied too early or too late.

When monitoring indicates an action level is reached, treatment is indicated.

Example: Once yellow starthistle, Centaurea solstitialis, *plants have set seed, treatments to control mature plants will not reduce the level of infestation next season or prevent seed rain into neighboring landscapes. Repeated monitoring in the early summer will allow treatments to be timed to catch the majority of the plants before they set seed.*

4. Apply Least Disruptive Control Tactics and Effective Revegetation Methods

Once monitoring has indicated that treatments are necessary, effective control and revegetation tactics must be selected. Decisions must be made about the type of control, details of application methods, and timing of treatments. This is discussed extensively in Chapter 5.

An ideal treatment will control the problem plant, encourage beneficial plants, and be most cost-effective in terms of the roadside life cycle cost. The perfect treatment will also achieve both short-term control of the problem and long-term prevention of its recurrence. Frequently, some compromise is required.

Example: For control of Canada thistle, Cirsium arvense, *managers have a choice of herbicide applications, mowing, and biological control techniques. Of these, biological control would be the least hazardous to human health, but would probably not provide adequate control by itself. Mowing is less toxic than herbicide applications. If done in the late summer, mowing provides effective control of Canada thistle without disrupting the predatory weevil that may be present and partially controlling thistle populations. Mowing height can be set at 12 to 14 inches to encourage competitive grasses which will help provide more permanent control in combination with the biological controls provided by the weevil. WSDOT already has the equipment and expertise for mowing treatments. The cost effectiveness of mowing is comparable to herbicide treatments in the short-term and if properly done, provides superior weed prevention in the long term.*

Treatments that encourage beneficial vegetation are sometimes (but not always) more costly in the short-term but usually lead to substantial reduction in long-term maintenance costs once the beneficial vegetation has become established. This is particularly true of areas with a history of weed problems.

Example: Some roadsides tend to have annual infestations of noxious weeds. Control efforts in many areas currently focus on herbicide use. Herbicides eliminate a variety of vegetation types and can create conditions ideal for the recurrence of weed problems. In the future, treatments should be followed by efforts to establish vegetation in the areas left open by the elimination of noxious weed populations. In some cases, past experience reveals effective treatment strategies.

Example: Spot treatment of Scotch broom, Cytisus scoparius, *and Himalayan blackberry,* Rubus discolor, *by mowing, treatment with Garlon4® and spring seeding of hard fescue and standard highway mix followed by fall mowing has lead to the development of healthy grass stands in place of the blackberry and broom thickets in some areas of Zone 2 in western Washington.*

In other cases, research or other technical expertise can offer guidance.

Example: L. L. Larson and M. L. McInnis of Oregon State University tested the ability of several grasses to suppress spotted knapweed, Centaurea maculosa. *'Paiute' orchardgrass* Dactylis glomerata, *and 'Critana' thickspike wheatgrass,* Agropyron dasystachyum, *were superior to 'Ephraim' wheatgrass,* Agropyron cristatum, *and 'Covar' sheep fescue,* Festuca ovina, *in terms of suppressing knapweed growth. Grasses with early and rapid growth were the best competitors with knapweed and can effectively suppress this pest. Grasses which were slow to establish will not provide adequate control for several seasons. This information could be used to plan reseeding of areas that have a history of knapweed problems. Careful reading of the article reveals details about seeding rate and method. The authors used a seed drill with eighteen inches between rows and one seed placed every centimeter. The seeded area was disked prior to planting, and the seeding was completed in March.*

When treatments are applied, maintenance workers should take brief notes on site conditions. This is standard procedure for herbicide applications because of record-keeping requirements, but should also be done for mechanical removal, mowing, seeding, and planting operations. Maintenance workers should always record the name of the problem or beneficial plant species. Notes should include site identification, date, wind conditions, how wet the vegetation and soil are, vegetation height and density (tall, short, thin, thick, etc.), soil preparation, fertilizer, or irrigation use, etc.

Without records of the details involved in treatment applications, it may not be possible to evaluate the effectiveness of the treatments. Treatment records, when combined with information from monitoring records, will help the supervisor evaluate why a treatment did or did not meet management goals and determine the relative costs involved. A sample form for recording vegetation treatment information is provided in **Appendix 1.**

5. Evaluate Effectiveness of the Treatments and Adjust Accordingly

It is very important to monitor treatment effectiveness to insure that management goals are met in a cost-effective manner. Whenever a site is monitored, areas receiving prior treatment should be examined to see if the treatment goal was met and if no further problems developed as a consequence of treatment. When goals are not met, or further problems are created by treatments, the treatments need to be changed.

If treatment efforts fail to prevent recurrence of targeted problems, adjustments will also be necessary.

Example: Research suggests mowing may help suppress spotted knapweed, but only if mowing heights are set such that competing beneficial vegetation is not adversely affected. During the startup period, one or more areas of knapweed infestation which also host beneficial plants could be designated as test areas to receive mowing treatments at several different heights and no herbicide applications. Several different mowing heights and frequencies can be compared with adjacent areas receiving typical control treatments and an area receiving no treatment. The comparative information gathered can be used to determine if mowing at specific heights and frequencies can be an effective tool for managing knapweed along roadsides.

6. Continue Monitoring and Evaluating

All sites scheduled for monitoring should be visited at least twice per season. Once to determine what, if any, management action is needed, and again to evaluate if the management action achieved the objective.

Information gathered through monitoring should be evaluated and used to refine all parts of the IVM process. (See also Chapter 6, “Evaluating the Effectiveness of the IVM Program.”) Experience will reveal what kinds of adjustments are needed in the design of the monitoring program. Management goals change as the vegetation on a site matures or public needs and concerns shift, so management goals should be reevaluated in each monitoring cycle. New plants may invade a site or old problem plants may be eliminated, so the process of identifying pests and setting injury levels and action thresholds should be repeated. Changes in goals and the types of vegetation on a site may mandate shifts in monitoring techniques, timing, placement, and personnel.

Monitoring must be repeated throughout critical periods in the season to catch plant problems before they exceed action thresholds. Treatment choices may change as experience reveals which techniques work and which fail, new weed problems develop requiring different treatments, or new treatment technologies and techniques become known and available. Existing treatments may need to be reapplied or replaced with more effective ones. Evaluation of treated areas must be repeated to control costs and insure management goals are reached.

4:P:DP/IVM

Chapter 3 Designing and Implementing a Monitoring Program

What Is a Monitoring Program?

The first and most important Integrated Vegetation Management (IVM) program component is the development and operation of a monitoring program. Monitoring involves *regular, repeated inspections* of the areas (including adjacent lands) where vegetation management problems might occur, and keeping records of observations. It means observing the overall condition of the roadside and paying close attention to specific plant and weed populations as well as human behavior and weather. Monitoring is an ongoing activity throughout any IVM program. *Once-only inspections are not monitoring because they do not reveal whether conditions are changing or how quickly change is occurring.*

In order to achieve the IVM goal of establishing relatively stable communities of desirable vegetation along roads, a manager must have some means of evaluating how well the desirable vegetation is doing, whether problem vegetation is present and expanding, and how well previously used methods of management are working. The manager must also gain an understanding of how roadside vegetation is changing over time. The purpose of monitoring is to gather and record such site-specific information so that it may be used to make decisions about *treatments*. Monitoring enables the manager to:

- Determine if and when treatments are needed
- Select, time, and place treatments
- Evaluate and fine-tune treatment actions

A monitoring program helps you become familiar with the workings of the natural succession processes in roadside plant communities. This knowledge can help you learn to *anticipate* conditions that can trigger plant management problems, and thus *prevent* them from occurring or catch them before they become serious. The documentation aspect of a monitoring program also provides consistent site information when personnel changes occur.

Monitoring methods may be periodically modified based on experience in the field. The length of time between monitoring events and the level of detail of monitoring efforts will vary depending on season, roadside conditions, staff resources, and severity of vegetation problems. It is important to keep in mind *that any level of monitoring effort is better than none at all*.

Determine If and When Treatment is Needed

Decisions about whether treatment actions are needed must be based on knowledge of what conditions pose a threat (the *injury level*) and whether the problem has reached a point when treatment must be applied to prevent the injury level from being reached (*action threshold*). Biological characteristics, public acceptance of the plants, state policy concerning noxious weeds, the Washington State Department of Transportation (WSDOT) mowing, weed, and brush control policies, and available budget all affect the setting of injury levels and action thresholds. This process will be explained in detail in Chapter 4, "Deciding When and Where to Apply Treatments."

Injury levels and action thresholds relate closely to the level of service that maintenance personnel are able to deliver. These levels should be somewhat consistent statewide and will be in direct proportion to the level of funding provided by the legislature. In determining these levels it is most important to consider both short and long-term costs.

Monitoring data may be used to help set injury levels and action thresholds by providing information about the impact of vegetation conditions on the achievement of *functional objectives*. Monitoring will also reveal when conditions approach action thresholds and thus guide treatment decisions.

Examples: Once the injury levels and action thresholds have been set, monitoring can determine the number of Scotch broom, Cytisus scoparius*, plants that can be tolerated per acre of Zone 2 roadside and how many will create a need for repeated, costly control efforts. Monitoring can show if there is a high enough percentage of ground covered by a beneficial plant community to prevent broadleaf weed germination and survival. Monitoring can indicate whether or not the timing of last month's mowing treatment on a new planting encouraged the plant species that was seeded to compete with weeds.*

Even when tolerance for the presence of a plant (and thus the action level) is near zero, such as for plants designated as Class A noxious weeds, monitoring will result in early detection of the pest vegetation, reducing the likelihood of unexpected or uncontrolled outbreaks.

Select, Time, and Place Treatments

Once the need for treatment has been determined, appropriate treatments must be selected, the timing of treatment decided, and the placement chosen before treatments are applied. Chapter 4, "Deciding When and Where to Apply Treatments" and Chapter 5, "Selecting and Applying Treatments," will discuss this process in detail.

Example: A manager may select a cutting treatment to control red alder at a site where the trees block visibility and pose a treefall hazard. Cutting could be accomplished manually or a brush hog could be used where saplings are growing in a dense stand. Cutting height should be as close to the ground as possible, and should be timed to be done in June or July to prevent re-sprouting (DeBell and Turpin 1989). Through monitoring, maintenance personnel identify the places where alder occurs in excess of the action level and focus spot treatments in those places.

Evaluate and Fine-Tune Treatment Actions

It is vital for managers to determine if treatment actions are effective and what improvements, if any, may be made on them in future. Monitoring may be used to provide information to evaluate treatments. Questions to ask include:

- Did the treatment reduce the cover of weeds or the vegetation problem below injury levels and/or increase the cover of beneficial vegetation?

- How long did the effect last?
- Were repeat treatments needed?
- If it was not successful, why not?
- Were there undesirable side effects?
- Are adjustments needed? If so, what?

What Information Should be Collected?

A well-designed monitoring program should contain certain types of information. These include *site background information* and *current conditions.* Site background information is historical in nature and needs to be collected only once. Information about current conditions changes over time, and must be gathered repeatedly through ongoing monitoring efforts.

Site Background Data

The first step in designing and establishing a monitoring program is to gather a wide variety of information, including background information on the site and plants that grow there. By focusing too narrowly on the plants themselves, important details are missed that help explain why vegetation management problems are occurring and how roadside maintenance operations can be redesigned to prevent future problems. Frequently, the design of roadside structures, species of plant materials chosen for landscaping or seeding, growing conditions (slope, soil type, degree or shade, precipitation and temperature distribution over the year, etc.) and/or the maintenance practices used to establish desirable vegetation or control problem vegetation actually trigger or intensify vegetation problems.

Thus, background information on the soil, history of vegetation management problems, maintenance efforts and practices, adjacent land use, roadside maintenance practices and procedures, etc., will help managers decide which plant species or conditions require priority attention. **See Appendix 1** for a Sample Site Description form.

How much information to gather is a function of how much time can be devoted to monitoring and how serious the actual or anticipated problem is considered to be. Early in the implementation of this type of program, it is likely that the initial focus will be on the most difficult *problem areas*. These areas are one of the types of *focus areas* for monitoring efforts defined later in this chapter. Examples of initial background data to be gathered when setting up the program include:

- **When** is this information being collected?
- **Where** is the site?
- **Who** is collecting the information?
- **What are the functional objectives** for the site?
- **What roadside zones** are present and where are the edges?
- **What are the vegetation management problems** of concern in relation to these objectives?

- **How extensive or serious** is each problem?
- **When in the season** does each problem occur?
- **What are the seasonal weather conditions** associated with the problem (i.e., warm or cold winter, early or late rains, unusually dry or wet overall, etc.)?
- **What is the condition** of the plant(s), soil, and roadside structures?
- **Where did landscape plant material, fill material, or mulch originate** (i.e., weed-free source)?
- **What are the current management practices** used along the roadside and on adjacent road surfaces and structures in areas with significant problem vegetation?
- **What other vegetation problems** exist on the site?
- **What are basic management procedures** used in this section of the maintenance area (e.g., mowing, spraying, ditch cleaning, plant material ordering, budgeting, etc.)?
- **What are relevant social/psychological factors** (e.g., neighboring landholder attitudes, local custom, management styles, etc.) that impact roadside vegetation management?
- **How long** has the road segment been in service?
- **What is the history of adjacent land uses**?
- **What are the probable causes** of vegetation management problems?
- **What is the history of vegetation management** practices at the site?
- **Who has been responsible** for vegetation management in the past?

Answers to these questions should be incorporated on forms and maintained in a three-ring binder or entered into a computer file for periodic reference **(see Appendix 1 for sample forms)**. A computerized database can be used to store site history, monitoring data, and treatment actions and results as well as to schedule routine monitoring of the roadside system. When personnel change, this information can be accessed by new staff and help provide continuity.

Decision-making based on review and analysis of this information will be made easier if it is tied to the Geographic Information System (GIS) currently under development within WSDOT. Using a GIS program, monitoring information can be mapped to provide visual displays of site conditions, priority problem areas, and distribution of work related to a particular functional objective. This information would facilitate organizing work requirements to maximize operational efficiency. The following information would be useful as part of such a system:

Vegetation Inventories — detailed records of the types and location of vegetation along roadsides throughout WSDOT managed areas

Soil Inventories — records of the characteristics of soils in WSDOT managed areas and their suitability for different types of vegetation

Current Site Conditions and Constraints — complete records of other site characteristics such as location and types of structures present and any existing agreements with adjacent land owners

Detailed Maps — to show WSDOT ownership boundaries and local jurisdictions

Site Development Requirements, Potential and Objectives — a list of site specific criteria including suggestions from the department horticulturist, supervisors, and lead technicians

Long-Term Management Plans — maps and text describing the management time schedule, monitoring program, choice of tactics and treatments, periodic site evaluations to determine if objectives are being met, and future maintenance programs

Fish and Wildlife Inventories — records of the types and location of wildlife species within WSDOT managed lands

Threatened and Endangered Species Inventories — records of species and locations of plants and wildlife with regulatory status

Habitat Protection Needs — information on the location and special needs of critical habitats which will be put at risk by highway expansion and construction activities

Sites of Accidental Damage — location and plans for reclamation of roadsides damaged inadvertently by flooding, fire, chemical spills, etc.

Sites of Damage From Abuse by Adjacent Landowners — records of the location, timing, nature, and extent of roadside abuses such as plowing, burning, and removal of trees

Special Maintenance Areas — locations of Adopt-A-Highway sections, neighbor maintained sections, neighboring, chemical-sensitive individuals, and no-spray zones (e.g., where adjacent landowners maintain the roadside, or near school bus stops or other areas where persons at risk for pesticide exposure congregate, walk, or bicycle on the roadside).

This type of database could ultimately become available to area supervisors, lead technicians, and maintenance personnel. During the development of the database, WSDOT maintenance staff would have an active role in gathering the information to be contained in the database.

At the time of the writing of this manual, this type of computerized mapping system is under development. Until this and other database inventories are completed, however, supervisors and lead technicians will need to rely upon their own information gathering efforts and focus on the most problematic areas. During this interim period, the list of data types provided above will serve as an excellent "check list" for initial efforts at gathering baseline information as part of the development of a monitoring program.

Current Conditions: What to Look for When Monitoring

After the basic background information for the site has been gathered, and appropriate forms filled in, it is time to zero in more closely on *focus areas* of problem vegetation and areas where there are opportunities to enhance or encourage beneficial vegetation. From an IVM point of view, it is as important to understand how and why beneficial vegetation is occurring on the roadside as it is to understand how and why pest vegetation has become established.

The following information is needed for each plant or plant community affecting functional objectives for each zone on the site.

- **Benefit or problem.** What is the nature of the plants' impact on functional objectives for each zone of the site?
- **The problem or beneficial plant(s).** What species is it? Is it classified as a noxious weed? If so, is it an A, B, or C designate? How many individuals are present or percent area is covered? Where does it occur geographically, seasonally, in the microenvironment? What does it look like at various points in its growth cycle? When is it vulnerable to control treatments or in need of encouraging management?
- **Natural succession species.** What species will grow well and support functional objectives in Zones 2 and 3; where can seeds or plant material be obtained; what are effective establishment techniques for the plants?
- **Potential secondary problems.** Are there potential problem plant species growing on adjacent roadside segments or bordering lands?
- **Maintenance or other activities that may affect the vegetation.** What activities are maintenance crews performing regularly? The specifics of how mowing, spraying, or ditch-cleaning activities are done can affect vegetation. Is traffic or other public use of the facility causing any effect on vegetation (e.g., weed seeds falling off hay trucks)?
- **Highway design and/or construction aspects that may affect the vegetation.** Are there any aspects of the roadway's design or existing structure that are effecting the vegetation or roadside condition?
- **Random events.** Unanticipated events may affect the vegetation (e.g., accidents that kill plants, disturb soil, and invite invasion of noxious weeds; accidental fires which encourage or damage beneficial vegetation or noxious weeds; landslides, etc.).
- **Seasonal Weather.** How hot, cold, dry, wet, windy has it been in each season and what was the distribution of hot, cold, dry, and wet periods?

This information may need to be augmented from other resources, depending on what is known about each factor. Each of these factors is discussed below in more detail.

Benefit or Problem

Identify the functional objectives for each zone on the site and where the zones change, then *decide* what characteristics a plant must have to influence these objectives. For example, how tall does a plant have to be to block visibility on this curve? What types of plants might be suitable for establishing at the border with neighboring land? Is there vegetation present that occupies space but does not interfere with functional objectives and can be encouraged to spread? Evaluate the existing vegetation in terms of the functional objectives before deciding whether the vegetation is problematic or beneficial. Also, remember that “harmless” vegetation is quite likely to be beneficial since it may be competing with potential problem species.

The Problem or Beneficial Plant(s)

If you locate an individual plant, but you are not sure what species it is or what growth stage it is in, collect a specimen and get it identified. Consult a knowledgeable colleague, plant identification books, the department horticulturist, or the county extension agent.

If you know the species, read about its biology. Become educated about the plant’s habitat preferences, life cycle, natural enemies, and anything that is known about its management.

Natural Succession Species

Develop information on plants that grow well in your area with minimal maintenance and compete successfully with noxious weeds and other problem plants. Are any of these beneficial natural succession species present? Do you know how to manage the roadside to encourage them?

Example: You notice that one roadside area is a patchwork of knapweed and several grass species which form discreet bunches. You collect some samples of the grasses when they are producing seed and have them identified by the department horticulturist. It is discovered that these are desirable native bunch grasses. You would note their presence for reference during planning of maintenance activities for that roadside area.

Potential Secondary Problems

Are there plants present which, following removal of a competing problem plant, may become problems themselves? Is there a significant population of a potentially problematic plant species on an adjacent parcel of land? If so, make a note of what these potential problem plants are and where you saw them so that future monitoring can be focused appropriately.

Example: A slope on a property adjacent to the roadside segment has a well established and spreading Himalayan blackberry, Rubus discolor, *bramble. No blackberry has been found on the roadside area itself to date, but ditch cleaning activities have disturbed the soil recently. This area should be monitored for blackberry periodically, then more frequently if blackberry plants begin to make an appearance.*

Maintenance or Other Activities That May Affect Vegetation

Identify the maintenance practices or public activities around areas which are either newly invaded by problem species or have a history of chronic problems with vegetation. Often, mowing, spraying around structures, ditch-clearing, public use, or even landscaping activities such as fertilization or irrigation are contributing to the problem.

Example: Repeated appearance of Russian thistle, Salsola iberica, *in newly landscaped areas is tied to a single source of topsoil. The supplier is contacted and it is discovered that they have had problems with contaminated topsoil. A memo is sent to the construction office to notify them of this problem for future reference.*

Example: Knapweed, Centaurea *spp., begins to appear and spread along a single roadside segment that has not hosted knapweed in the past. Further investigation reveals that an adjacent land area has recently become popular with off-road bike enthusiasts, who are parking their cars and accessing the area from the roadside segment. Knapweed seeds from a significant distance away are being transported and dropped along the roadside, into bare soil freshly disturbed by bicycle and car tires.*

Highway Design and/or Construction Aspects That May Affect the Vegetation

Design and construction of the highway and roadside sometimes results in maintenance problems that do not show up for years after maintenance has taken responsibility. Are there aspects of the roadside or vegetation that are a result of the way the road was designed and constructed?

Random Events

Are there any random or out-of-the-ordinary human or other events that might affect the roadside vegetation?

Example: You notice a place in the median where the State Patrol has begun to regularly turn around to pursue speeding motorists. The grass stand is being disturbed by this activity and knapweed which was being suppressed by the grass is now sprouting in the tire tracks. You point this out to the superintendent and the state patrol is contacted to discuss possible solutions and alternatives.

Seasonal Weather

Years with different types of weather will favor different types of vegetation. The relationships between climate and vegetation are complex, but generally known to ecologists and land managers who deal with a given type of vegetation, i.e., grassland, shrubland, or forest. Keep a log of temperatures and of precipitation levels and patterns of distribution in your area. When was it hot or cold? How hot or cold did it get? When was there rain or snow, and how much fell? It may also be possible to obtain this information from a local source or through the Internet. This information could also be recorded and handled by the regional offices.

How to Gather Monitoring Information

Focusing Efforts Where They are Most Needed

Part of the process of creating a monitoring program is finding and defining different "*focus areas*" for monitoring efforts, including gathering management histories and baseline data. As discussed in Chapter 2, the number of focus areas will be limited at first and expand over time as the program becomes established. There are five important types of sites which should be subject to monitoring activities, each easily identified by its characteristics:

- **Problem Areas.** Some sites will have a continuing history of vegetation problems. These are often the most critical areas containing situations which are most in conflict with the maintenance objectives.
- **Sensitive Areas.** Specific sites with functional objectives above and beyond those typical for each roadside zone. Areas which serve as migration paths for animals, provide critical habitat for endangered or threatened species, or border on sensitive ecosystems such as riparian and wetland areas should be considered sensitive areas.
- **Model Areas.** Within the vast area of roadside in a maintenance area, it is likely there are one or more successful "natural experiments," where a competitive community of desirable plants, especially native species, has persisted on its own. Such an area should be monitored to learn more about why it is successful and what its history of management has been. Successful intentional plantings should also be monitored to track their progress.
- **Test Areas.** These are small areas set aside to be carefully monitored but not given usual treatments. This allows managers to evaluate the actual effects of treatments by providing an untreated comparison area. Test areas should be managed within guidelines for public safety and noxious weed control. **Appendix 2** explains how to create and maintain successful test areas.
- **Typical Areas.** There is a matrix of "average" roadside vegetation conditions connecting the types of "hot spots" listed above. Instead of attempting to monitor all of this area equally, a representative section can be chosen to receive more monitoring attention and be used to make decisions about the rest of the area or to alert managers to sudden changes in conditions that will likely affect the larger area. The areas of the roadside between the monitoring "focus areas" are given only a cursory inspection from a moving vehicle until the typical areas signal that additional vigilance is warranted.

Using a map, it should be possible to define these types of areas within a maintenance area or section of responsibility. Priorities can then be quickly and efficiently assigned.

Levels of Effort Used in Monitoring

Monitoring can vary from the extremely casual to statistically strict, depending on how serious the problem is considered to be. Information can be either *qualitative* (recorded as a relative amount using words such as "large," "small," "dense," "thin," etc.) or *quantitative* (recorded as specific numbers from counts, measures, or ratings on a numeric scale). The levels of effort, listed from casual to strict, are:

1. Hearsay or other person's casual looking
2. Casual looking with no record-keeping
3. Casual looking with written observations
4. Careful inspections with written observations
5. Regular written observations and quantitative descriptions
6. Quantitative sampling on a regular basis
7. Statistically valid quantitative samples

The idea is to match the level of monitoring effort to the importance of the problem. Levels 1 and 2 are the most common and least helpful; Level 3 is suited to a period of transition to IVM; Levels 4 and 5 are appropriate for a fully developed IVM program. Usually you start at Level 4 and progress to Level 5 only if it is thought the problem will become serious or recur. While a scientific study requires Level 7 precision, *most WSDOT maintenance personnel will most likely be using Levels 1 through 4*, with Levels 5 and 6 being utilized with the assistance of the department horticulturist and only in the most problematic areas or test areas.

Being good at noticing things is critical to vegetation management. It is particularly necessary to observe the *connections* among various elements in the roadside environment, including how human behavior affects the plants, problematic or beneficial. In order to have a successful IVM program, making observations needs to become a habit for maintenance personnel working with vegetation management.

Time necessary for effective monitoring decreases as more experience is gained. For example, after a season or two of experience, key problem species can be recognized from a distance or when they are very young. Key beneficial plants that should be encouraged with management also become easily recognized. *Counting plants* and *estimating cover* become fast, efficient activities.

Planning Monitoring Activities

Once locations for focusing information-gathering efforts have been determined, the following process for developing a monitoring program tailored to specific needs is suggested:

- Determine the **purpose** for the monitoring
- Determine **which vegetation characteristics** are to be sampled
- Decide **when** to sample
- Decide on the **frequency** of monitoring
- Determine **how large an area** to sample
- Describe the **monitoring procedure in writing**
- Make an easy-to-use **record-keeping system**
- Develop a system for **summarizing field data**
- Determine **who** is the best person to carry out the monitoring in the field
- **Evaluate** the monitoring and decision-making system
- **Make corrections** in the monitoring decision-making system

Determine the Purpose for the Monitoring

The purpose should be defined to help managers meet functional objectives for roadside areas in a cost-effective manner as well as demonstrate the results of budget impacts. For example, a monitoring program might be established to time weed and brush control activities and seeding of desirable plants, to catch problem weed species when they are vulnerable to cost-effective control, to see if desirable vegetation is producing seed or spreading, to time mowing for when the roadside vegetation is at a particular height, or to determine if a recent management activity successfully met management goals.

Determine Which Vegetation Characteristics are to be Sampled

Generally, the most useful types of data to collect about plants include:

- The amount of *cover* (the percentage of an area covered by a type of plant), estimated visually
- The *number* of individual plants present
- The *height* of the vegetation
- What *growth stage* (seedling, mature, flowering, setting seed, dormant, etc.) the plant is in

Appendix 3 details ways of qualifying and quantifying vegetation characteristics. **Appendix 4** explains techniques used in visual monitoring of vegetation.

Characteristics should be chosen that provide the *most information about how the vegetation is affecting roadside management objectives with the least amount of effort*. For example, a decision may be made to:

- Estimate the percentage of ground covered by desirable vegetation in Zone 2
- Estimate the amount of bare ground area to be seeded
- Count the number of Scotch broom plants seen along a quarter mile of roadside
- Measure the height of vegetation on a roadside curve
- Estimate the number of individual plants or total area covered by a noxious weed
- Rate germination success of a recently seeded area on a scale of 1 to 5
- Note whether or not tansy ragwort plants have reached the flowering growth stage

Vegetation that takes the form of large, distinct individuals is best quantified by counting individual plants. Otherwise, estimates of plant cover are easier and more accurate assessments of plant growth. Remember that *quantitative* data such as cover or the number of plants present may be more time consuming to collect, but this type of data can be used to set *injury levels* and *action thresholds* for optimizing management.

There are many tools and techniques that can make monitoring quick and accurate. **Appendix 5** provides a complete list of monitoring tools and details on the use of each. Standardized monitoring forms will contain space to indicate which tools and techniques were used to monitor specific areas and conditions.

Decide When to Sample

Monitoring should be *planned to reveal problems and opportunities when it will be effective and efficient to address them*. This means monitoring over a range of time during the growing season, not on arbitrary calendar dates. All plants have particular seasons when they typically germinate, grow rapidly, flower, and set seed.

Problem species may be easy to control when they are young but difficult to distinguish from other plants until they are more mature. It is a good idea to suppress problem species before they set seed. On the other hand, desirable vegetation should be allowed to go to seed. Monitoring should be timed to reveal when beneficial or problem vegetation is at a critical stage. Monitoring should also be timed, if possible, to fit into existing work schedules of road inspection which are typical for managers.

Decide on the Frequency of Monitoring Efforts

For problem plants, monitoring should be infrequent early in the season, just enough to determine where the problem plants are most abundant and thus where more intensive monitoring should be focused later. Monitoring should be more frequent during periods of the season when problem plants are passing through vulnerable stages of growth and should be frequent enough so that vulnerable stages are not missed or the problem plants allowed to set seed between inspections.

Example: Small populations of tansy ragwort, Senecio jacobaea*, can be effectively controlled by simply hand-pulling plants before they flower. The tall flower spikes are easy to recognize and serve as a handle for pulling. Casual monitoring early in the season can be used to spot and record locations of young tansy. More intensive monitoring later in the season will be needed to note when flower spikes have formed and the tansy should be pulled (Prull 1989).*

For desirable plants, monitoring efforts should be frequent at times in the season when the plants are at a stage when they may need management intervention such as mowing or occasional watering to establish successfully.

It is important to remember that plants can move through growth phases very quickly. This is particularly true of weedy annual plants, which can go from small to fully grown and setting seed in a period of two weeks in the spring. In all cases, when setting monitoring frequency, *it is better to rely on experience and observation rather than on rigid schedules set by convenience on a calendar*.

Determine How Large an Area to Sample

A given roadside segment is likely to be a relatively uniform environment, so inspecting a portion of it will usually enable managers to generalize about the rest. Simple visual inspections can provide an overview, then if necessary, a smaller more critical area can be selected for more careful, quantitative evaluation.

Describe the Monitoring Procedure in Writing

Methods used to sample should be written down. This enables the person doing the monitoring to recall details from one inspection to the next. It also enables monitoring duties to be passed on to other staff without errors being introduced. A written procedure also maintains a historical record of monitoring efforts that can be referred to when evaluating how well the monitoring methods work.

Make an Easy-to-Use Record-Keeping System

The person doing the monitoring should have a minimal amount of writing to do. To the degree possible, data should be recorded by checking off or circling the appropriate number or comment. Rating scales and abbreviations should be used to maintain accuracy and save time. Make the data sheets as complete as possible, since each blank on a form helps the observer remember what to sample. Data sheets should also be “test driven” before being mass produced. It may take several revisions to arrive at the most useful record keeping sheet. Data sheets should always include a record of the site location, the date, and the name of the person making observations. A detailed discussion about optimizing record-keeping is provided in **Appendix 6.** WSDOT will develop a set of standard monitoring forms during the process of IVM adoption.

Develop a System for Summarizing Field Data

The information collected must be assembled in a meaningful way so that patterns will emerge to facilitate decision-making. Patterns of success in encouraging or establishing desirable vegetation and controlling problem vegetation can then be correlated with site conditions and past management practices. **Figure 3-1** illustrates the use of pie charts to visually summarize monitoring data.

Determine Who is the Best Person to Carry Out the Monitoring in the Field

This may be dictated by the duties assigned to different personnel. Generally, it is best to choose the person who is most frequently out on the road in the area. It is also preferred to have one or two individuals be the principle samplers to maintain consistency and help insure that someone is gaining an understanding of the “big picture” for the maintenance area.

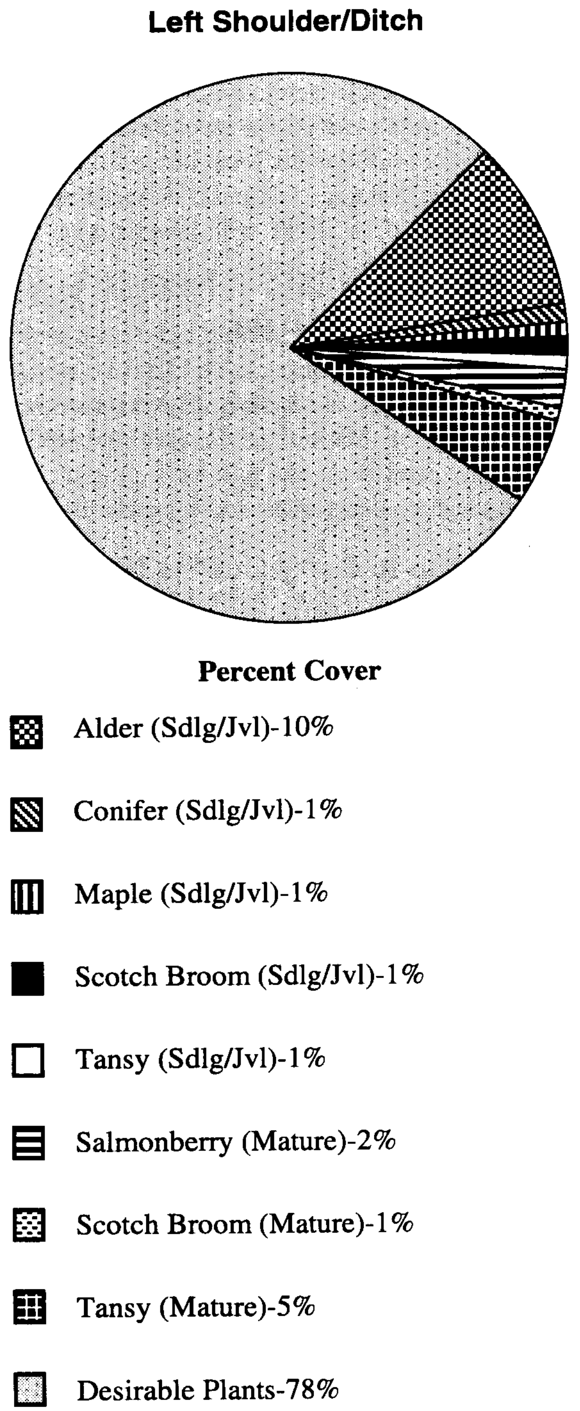
Evaluate the Monitoring and Decision-Making System

As data is assembled, potential changes in the monitoring process that could improve precision, accuracy, or efficiency and cost-effectiveness may become evident. Make notes of such ideas for later use. For example, if the monitoring system did not adequately warn of noxious weed problems or the failure of desirable vegetation to establish, then the system should be modified accordingly. Was the cost of monitoring and record-keeping worthwhile? Was the cost of management worth the value derived from the management? Chapter 6 provides a more detailed discussion of how to evaluate each component of an IVM program.

Make Corrections in the Monitoring Decision-Making System

Record the changes so a written history is maintained for later review purposes.

5:P:DP/IVM



Example Roadside Vegetation Inventory

Figure 3-1

Chapter 4 Deciding When and Where to Apply Treatments

Introduction

Once a functional monitoring program has been developed and focal points for monitoring efforts chosen, monitoring efforts must focus in on targeting problems and identifying optimal solutions. Details about precisely when and where treatments will be applied must be determined.

Identifying Key Beneficial and Problem Plants

Within monitoring focal points, the manager must concentrate on key beneficial and problem plants. *Current conditions* data from the first season of monitoring combined with *site background data* will enable managers to determine the key plants along the roadsides. Key problem plants are those most likely to interfere with functional objectives on a roadside site or are considered noxious weeds. Key beneficial plants are those most likely to promote functional objectives by out-competing weeds and preventing erosion. Some may be neutral in regards to functional objectives but vigorous and persistent and thus potentially beneficial.

By identifying key problem and beneficial plants and their locations in the roadside system, monitoring efforts can be focused primarily on those species, while a less intense watch is kept over other plants and plant communities. This information can also be used to reduce noxious weed and general nuisance vegetation problems by changing or eliminating practices which monitoring has shown to create problems.

Example: Maintenance staff are required to control vegetation around guardrail posts. This is usually accomplished by spraying out all vegetation within a yard or more of the guardrail. However, monitoring has shown that this practice creates a bare area for problem plants to colonize, and thus creates the need for more frequent and stronger herbicide applications in the future. A more cost-effective long term approach would be to revise the standard construction detail to include an extension of the asphalt shoulder under and around the guardrail posts.

To determine key beneficial plant species or communities, collect written observations and maintenance crew experience concerning which plants persist along the roadsides but do not interfere with functional objectives. Species already established on a site are best adapted to it, and thus likely to be the easiest to manage for. They may also produce enough seed or runners to provide all the planting material needed, saving the cost of purchasing seed or raising seedlings. Combine these findings with advice from the department horticulturist, who will use his or her own experience and the knowledge of other experts to suggest other species to introduce into the system.

If there is quantitative data available, rank beneficials by:

- Vigor
- Degree of weed suppression
- Ease of establishment or enhancement

- Cost of establishment or enhancement

To determine key problem species, collect written observations about which species of plants have become problematic, organized by why they are a problem (i.e., if they are classified as a noxious weed and/or what functional objectives they tend to interfere with). Rank the average counts of the following:

- Number of times the plant has required control in a given year
- Number of instances where the plant has required repeated control efforts in the same location
- Number of repeated control efforts needed to effectively suppress the plant with existing control strategies
- Number of vegetation areas receiving control treatments, organized by type of treatment

Once key plants have been identified, maintenance crews should be trained to watch for key beneficial and problem species and to apply the best known management practices to encourage or suppress each, respectively. Over time, this basic strategy will catalyze the gradual replacement of problem plants with beneficials throughout the roadside system, with accompanying increase in the quality of roadside management, reduction in cost of management, and greatly reduced herbicide use.

Determining Injury Levels

Ideally, maintenance should be conducted to prevent the recurrence of problems as well as eliminate current ones. Over the long run, prevention is both more effective and less costly. In practice, total eradication and prevention of the recurrence of an organism is virtually impossible to achieve. A more realistic goal is to determine the *level* (or amount) of problem plants or interference with functional objectives that can be tolerated without compromising those objectives. The same principle can be applied to determining the *level* of loss of beneficial vegetation that is tolerable without inviting problem plants to invade. Treatments are applied only if intolerable levels are likely to be reached. This involves determining *injury levels*.

The *injury level* is the point in the growth in the problem plant population (or decline in the beneficial plant population) when the number of individual plants, percent cover, or the measure of some plant characteristic (such as height) is sufficient to cause some unacceptable kind or degree of impact on functional objectives. This level will vary in some cases depending upon budget variations, but three values comprise an injury level:

- The amount of functional, economic, or aesthetic damage that justifies the cost of applying a treatment
- The population size, area of cover, or quantity of some other plant characteristic that causes intolerable interference with functional objectives
- The cost of controlling the problem plant to prevent the injury level from being reached

The amount of functional, economic, or aesthetic damage that justifies the cost of applying a treatment.

Example: A few scattered broadleaf weeds within a stand of desirable grassland plants will not be a concern to a farmer whose field borders a roadside. Large clumps or significant numbers of plants producing seeds could cause significant economic losses for the farmer in the following season when seeds from the weeds germinate in the farmer's field. Use monitoring records coupled with records of calls or complaints from neighboring farmers to set the injury level for the vegetation in a given area.

The population size, area of cover, or quantity of some other plant characteristic that causes intolerable interference with functional objectives.

Example: Below a certain height and density of growth, a stand of evergreen trees does not contribute to a frost and shading problem along a stretch of north/south highway. When individual trees reach a height between 30 feet and 40 feet they begin to add shade to pavement in the morning and evening hours. A long term program needs to be established which selectively removes trees between 30 feet and 40 feet every four years.

The cost of controlling the problem plant to prevent the injury level from being reached.

If an area suffers chronic plant problems requiring repeated treatments, it may be cost-effective to start over and replant the area with beneficial plants.

Example: A landscape planting of redtwig dogwood, Cornus stolonifera, *requires regular trimming in one area to maintain visibility of a sign. The most cost effective solution would be to remove the plants requiring the trimming and replace them with a dwarf variety of the same species.*

Treatments are usually based on some notion (usually unspoken or informal) of injury level. Roadside managers frequently act on injury level concepts they have inherited from previous managers or casually accepted along with others in the system. The process of recording and summarizing the information as outlined above will make explicit whatever working injury levels are being used, and help evaluate them in relation to overall maintenance priorities. This type of evaluation may also be useful in other aspects of highway maintenance such as pavement management, hydraulics, guardrail repair, etc.

When an Integrated Vegetation Management (IVM) program is first implemented for a roadside maintenance area, guidance on setting the injury level may be available from existing maintenance records, statewide maintenance policies, from literature on the management of plants, through discussions with those who have experience managing a particular plant species in a specific area, or from the recollections of maintenance staff about problems that occurred in prior years.

During the start-up phase, it is wise to be conservative when establishing an initial injury level and even limit the application and documentation of this principle to the most critical problems. Where it is applied, set the injury level low enough (i.e., low numbers or percent cover of problem plants or only a slight decline in beneficial plant cover or number) to insure a wide margin of safety while IVM skills are being developed. However low or high the initial injury level is set, something is needed to compare it with so it can be learned if treatment was unnecessary or applied sooner, more frequently, or later than needed.

The easiest way to collect comparative data is to set aside an area that is left untreated at the time the surrounding area receives treatment. Mark this area with flags or stakes. By monitoring the untreated area frequently over the course of the year, the manager will learn whether the injury level needs to be adjusted up or down for the next year. **Appendix 2** explains how to create and manage test areas in more detail.

For the decision-making process to yield effective vegetation management, the injury level should be periodically re-evaluated for each key plant species and for each site. Changes in budget levels, climatic conditions, plant species present in planted areas, horticultural or management practices, IVM experience level of employees, or public needs can affect the setting of injury levels.

On What Does the Injury Level Depend?

As suggested above, there are a number of factors which influence the decision that a specific plant is creating a serious problem, or that a planting of beneficial vegetation needs care. It is not sufficient to say that there is a problem just because a plant commonly considered a problem is present, or a new planting of beneficials is not meeting initial expectations. It is necessary to ask at least the following questions before deciding whether or not the injury level is likely to be reached.

What Is the Potential for Problems?

The answer to this question involves the following variables:

- Identity of the plants (problem and beneficial)
- Plant size and abundance
- Overall health of roadside vegetation and condition of roadway structures
- Seasonal conditions and microhabitat
- Tolerance of the public to interference with roadway function

Problem or Beneficial Species

It is important to identify the plants in question. Not all broadleaf weeds are alike, nor are all beneficial grasses. Not all sites are equally sensitive to a given problem plant in terms of meeting functional objectives.

Example: Control of noxious weeds is one of the functional objectives of the the Washington State Department of Transportation (WSDOT) roadside vegetation management program. Knapweed, Centaurea *spp., is a target for control because it is on the state noxious weed list and has a tremendous potential to spread. In one situation the weeds are infesting the neighboring property as well as Zones 2 and 3 of the right of way. In another situation a few plants have appeared over the past two years in an area previously uninhabited by any knapweed. The injury level should be set lower for the infested area (i.e., tolerance for the plant is low) and higher for the area with the recent occurrence.*

Plant Size and Abundance

Are the problem plants large or numerous enough to be a problem? Are the beneficial plants dense enough to inhibit weeds?

Example: If the grasses and shrubs along a curved roadside are not tall enough to block visibility, they do not present a problem in terms of the functional objective of maintaining visibility on that curve.

Overall Health of Roadside Vegetation and Condition of Roadway Structures

Areas where vegetation is disturbed and a lot of bare ground is present, or areas where problem vegetation has been chronic, are particularly likely to need treatment. Potential problem species in these areas should be given low injury levels (indicating low tolerance). Also, older structures may be more vulnerable to damage from vegetation than newer structures that are in better condition. Thus vegetation in proximity of older structures might be given lower injury levels than plants next to newer structures.

Examples: One particular median area has been subject to frequent disturbance by motorists turning their vehicles around. Injury levels for noxious weeds should be particularly low here because of the potential for the weed to invade and spread rapidly through the disturbed soil and in the surrounding median. A long-term solution would be to create a paved turnaround at this location if it is safe and legal, or if not, to take some other measure to prevent illegal U-turns.

Seasonal Conditions and Micro-Habitat

Different species of plants, whether problem or beneficial, respond to different yearly weather patterns and the temperature, humidity, light intensity, and soil characteristics of the exact place they are growing. When environmental site conditions are favorable to a problem plant but discouraging to beneficial vegetation, injury levels are set low. When conditions discourage problem plants but support beneficial plants, injury levels are set higher.

Example: On a section of a recently widened section of roadway there are cut slopes on both north and south sides of the road. Both slopes have been seeded with grass and planted with Douglas fir, Pseudotsuga menziesii, *and cedar,* Cedrus *spp., 15 feet on center. There are old existing stands of Scotch broom,* Cytisus scoparius, *in the area. Since the broom will not compete as well on the north facing slope, the injury level may be set higher on the north side and lower on the south side.*

Tolerance of the Public to Interference With Roadway Function

If asked, most people would probably state they have very low or zero tolerance for vegetation problems which affect roadsides. In practice, however, public tolerance will vary depending on whether the road is in an urban or rural area, bordering public land or private land, whether the roadside was landscaped with ornamentals, and so on.

Examples: A ranch operator may have a relatively high tolerance level for broadleaf weed species along adjacent roadsides, but a farmer may have a very low or zero tolerance.

A highly landscaped area inside an urban interchange is becoming host to a variety of grasses and herbaceous plants. These plants have little or no impact on visibility, drainage, or pavement integrity, but they stand out visually from the ornamental species. Motorists find the vegetation "out of place" and express a very low tolerance for it.

Since being “a good neighbor” is one of the overall objectives of roadside vegetation management and WSDOT has a strong customer focus, managers are obliged to consider public input. When transitioning to an IVM program, some public outreach and education may be necessary to demonstrate the benefits of the program to the public. Chapter 7 provides a more complete discussion of education and outreach strategies. Hopefully, public perceptions of roadside vegetation will harmonize with IVM goals and procedures in the long run.

Example: When road departments in Iowa began implementing IVM and revegetating roadsides with historic prairie plants, effort was placed on education programs explaining the history and function of these plants and the prairie “look” beginning to develop along the state’s roads. This effort was targeted both at the general public and policy makers, as well as to road engineers and maintenance personnel. Alliances with the state’s tourism industry was also a component of the education program.

Determining Action Thresholds

The *action threshold* is the point (in time or in terms of some quantity concerning plant characteristics) when a treatment must take place to prevent vegetation conditions from reaching the injury level. Determining the action threshold involves making educated guesses about the likely *future effects of present conditions*. In other words, it is necessary to estimate how much the situation is likely to change over the season and whether some problem will result if no action is taken this season. Will a potential problem plant become a problem, or will beneficial competitive vegetation or other factors limit its growth and reproduction? Are growing conditions particularly favorable to a problem plant species, or do they favor competing beneficials?

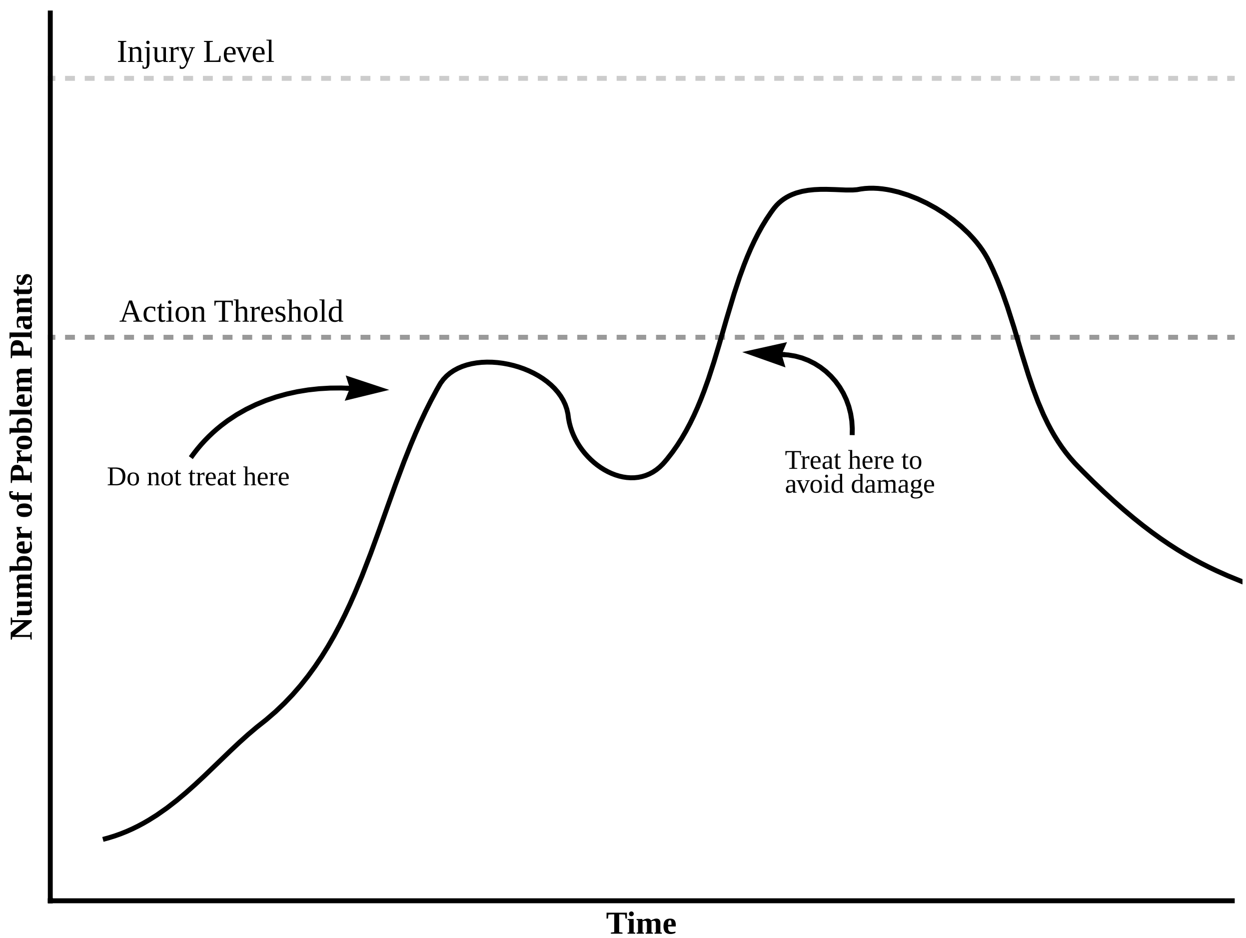
The action threshold must be determined and treatments applied *before* the injury level is reached. **Figure 4-1** illustrates the relationship between the injury level and the action threshold. An important variable in setting the action threshold is the amount of time required to prepare for a given treatment. One can call this the *action preparation time*. Working backwards in time from the action threshold, one can determine a point in time when a decision about each treatment must be made and plans for action should start if intolerable damage is to be prevented. This is called the *decision point*.

In situations where treatment means application of an herbicide, action often takes place long *before* it can be predicted that the injury level will be reached. These are sometimes thought of as “preventive treatments,” often applied on a calendar basis. In many cases they are premature and, by damaging beneficial vegetation and creating bare areas early in the growing season, probably trigger more problems than they prevent.

However, if pressure from hard-to-control weed species such as knapweed, *Centaurea* spp., and Scotch broom, *Cytisus scoparius*, is high this year or has been in previous years on a particular site, preventive treatment early in the season may be warranted, and may preclude the need to treat several times later on. Use monitoring data to assess *each year* whether preventive treatments are needed rather than routinely applying them. When choosing preventive treatments, select effective ones that will not harm beneficial vegetation on the site.

Sometimes action takes place after a problem plant population has begun to decline or after it has set seed and begun to die back. Such treatments might be called "revenge" treatments and they serve no management function. They are useless (at best), wasteful, and may trigger new problems (at worst).

6:P:DP/IVM



The Relationship Between Injury Level and Action Threshold

Figure 4-1

Vegetation Management: Strategies, Tactics, and Treatments

The primary goals of the Washington State Department of Transportation (WSDOT) Vegetation Management Program are to ensure safe mobility and preservation of the roadway system. Other objectives of the program are to provide soil and slope stability, control noxious weeds, provide storm water drainage and biofiltration, maintain fire control, and enhance roadside aesthetics and compatible wildlife habitat. All of these goals may be achieved through establishment of stable roadside vegetation that will resist encroachment by undesirable plants and thus minimize difficult and costly reactionary management.

A number of vegetation management strategies, tactics, and treatments are used to encourage desirable vegetation and discourage unwanted plants. A strategy is an overall approach to solving a vegetation problem, such as using “biological control” to suppress a noxious weed. A tactic is a type of action or series of actions within that strategy. Releasing a predatory flea beetle to control tansy ragwort is an example of a biological control tactic. A treatment is a very specific set of choices which details exactly what action will be taken, where it will be taken, and how. Releasing 300 commercially reared flea beetles in the tansy ragwort patch at milepost 116 during the morning hours of a clear day in mid-April is an example of a treatment for the tansy ragwort problem on this site. Unlike strategies and tactics, treatments are almost always specific to the target species and the site.

The Integrated Vegetation Management (IVM) concept is based on the fact that combined strategies for vegetation management are more effective in the long run than a single strategy, tactic, or treatment. Thus, while the examples provided in this manual generally focus on a single tactic or treatment, in practice two or more strategies are usually used together to solve a site-specific vegetation problem.

In terms of planning, it is important to consider the range of strategies available and, within each strategy, the range of tactics which might work for a given situation. Once the possible strategies and tactics are identified, treatments may be specified (designed) by considering both the objectives for treatment and certain criteria for optimizing treatment selection. Defining viable strategies and possible tactics within each will probably be handled at a statewide or regional level through a long-term planning process. Designing and specifying treatments from all of the possible tactics known to WSDOT will probably occur in the short-term at the region or area level and may require additional communication between managers and WSDOT technical support staff such as the staff horticulturist.

The first section of this chapter will discuss the families of treatment strategies and provide examples of related tactics and treatments derived from them. The second part of the chapter will discuss treatment objectives and criteria for selection. The third section will discuss treatment timing, rate, and placement. It is not possible to provide details of every available tactic and possible treatment in the space allotted for this manual. Throughout the text, examples illustrate some of the tactics used in treatments which may be applied in situations typical of WSDOT roadside vegetation management. Over time, through gathering of site background data, information on current roadside vegetation conditions, review of existing WSDOT knowledge, and consultation with technical experts in a variety of fields, WSDOT will develop a complete and detailed reference on tactics and records of successful and unsuccessful treatments. Supervisors, lead technicians, and other WSDOT personnel will have access to this reference when making treatment decisions.

IVM Strategies and Related Tactics

IVM Vegetation management strategies fall into one of two general categories:

- Prevention of problem vegetation (establishment of desirable vegetation)
- Suppression of Problem Vegetation

Both approaches are employed in an IVM program.

Strategies and Tactics for Prevention of Problem Vegetation

This approach focuses on understanding the biological requirements for plant survival and the ecological relationships among plants. The goal is to enhance conditions for preferred competitive vegetation and reduce conditions conducive to undesirable vegetation types. Healthy, relatively stable plant communities resist the invasion of pest vegetation by occupying all growing space at a site, thus denying undesirable plants the access to nutrients, water, light, and other resources they require to survive. **Box 5-A** lists highway sites and conditions currently requiring vegetation treatments and examples of desirable vegetation types for meeting long-term maintenance needs.

Problem plant prevention strategies include:

- Development or restoration of beneficial plant communities
- Manipulation of natural plant succession processes
- Habitat modification
- Enhancement of ecosystem diversity
- Changes in human behavior
- Education

Development or Restoration of Beneficial Plant Communities

Prevention of problem vegetation can be accomplished through the general strategy of promoting beneficial plant communities along roadsides. Tactics include maintenance to enhance existing populations of native plants on site, site preparation and seeding of desired plant species, and transplanting of desired plant species.

Box 5-A. Desirable Vegetation Types for Conditions on Highway Roadsides

- Pavement edge (Situations with no Zone 1): Low-growing vegetation that does not produce invasive roots and is fire retardant (i.e., perennials or summer annuals).
- At the base of roadside signage and hardware (Zone 2): Moderately low-growing perennials or summer annuals that retard fire.
- Drainage ditches and culvert inlets and outlets (Zone 2): Moderately low-growing grasses and forbs that will provide natural biofiltration, and reduce scouring but will not impede drainage.
- Sight distance (Zones 2 and 3): Moderately low-growing shrubs, groundcovers or grasses that will not block horizontal or vertical visibility of safety hardware, traffic conditions, etc.
- Highway corridors (Zones 2 and 3) with pedestrian and bicycle paths: Moderately low-growing grasses, forbs, shrubs, or widely-spaced trees with adequate clearance for visibility and safe passage.
- Vehicle recovery areas (Zone 2): Herbaceous vegetation and shrubs that will not produce stems greater than 3 inches in diameter.
- Landscaped areas (interchanges, medians, Zones 2 and 3): Native or naturally adapted grasses, groundcovers, shrubs, and trees that are drought-tolerant, pest-resistant, and have low maintenance requirements.
- Backslopes (Zone 3): Native grasses, forbs, shrubs, and trees that encourage soil stability, biodiversity, wildlife habitat, protection of rare and endangered species, and other cultural, environmental, and aesthetic values.

The most cost-effective strategy for achieving problem vegetation prevention for Zone 3 and some Zone 2 areas is to develop and expand the beneficial vegetation already adapted to a specific site. Such vegetation usually includes both native plants as well as introduced (nonnative) species. There is a positive role for both native and certain nonnative plants on the roadsides. However, native vegetation is generally preferred over introduced plants for a variety of reasons. These range from better adaptation to site conditions and greater resistance to pest insects and pathogens, to better habitat and forage for roadside-compatible wildlife, conservation of gene pool resources, and aesthetics that blend in with adjacent natural environments. Once established, native plants generally require only occasional maintenance and are usually capable of surviving and/or regenerating after droughts, excessive rainfall, temperature extremes, etc.

Native vegetation in the state of Washington varies from bunchgrass dominated steppe communities to some of the tallest, most productive forest communities on earth. The vast differences in vegetation zones are largely a response to the wide variation in annual precipitation which ranges from a low of 7 inches in the Columbia Basin to over 240 inches in the Olympic Peninsula.

Environmental conditions along State highways vary significantly, especially between western and eastern Washington (see **Figure 5-1**). The selection of appropriate vegetation for seeding or transplanting will depend on a wide variety of environmental factors such as temperature, soils, moisture, nutrients, sun exposure, air and water quality, wind conditions, and availability of plant material. Chapter 1320 Vegetation, of the WSDOT *Design Manual*, Section 1320.03 paragraph (2) Plant Selection, identifies the criteria for proper selection of the various vegetation types. Appendix 7 contains a description of native vegetation characteristic of the State's Vegetation Zones along with suggestions of native plants for revegetation projects on roadsides in various vegetation hardiness zones. Information on rare and endangered plants and ornamental species commonly found on roadsides is also provided.

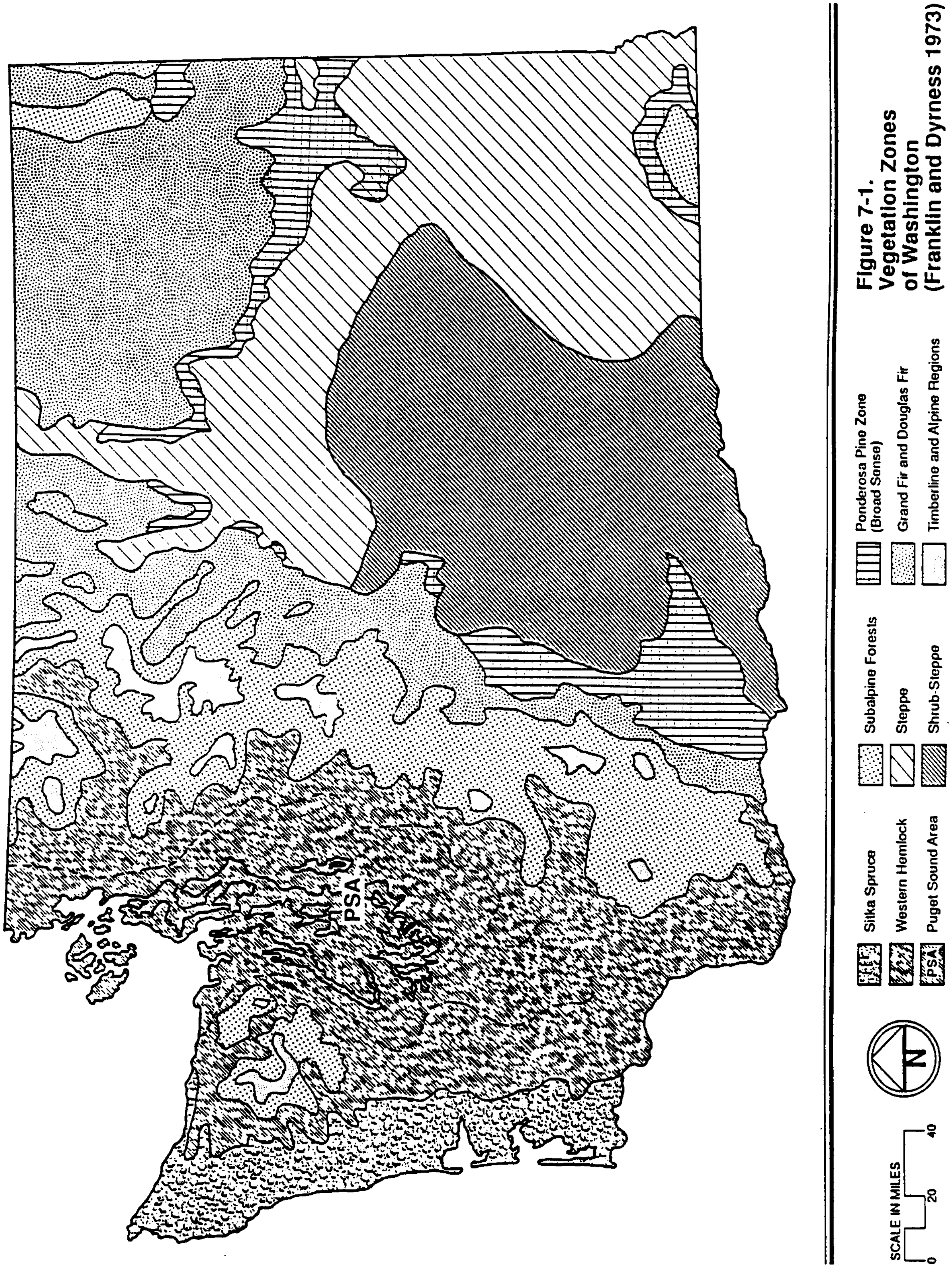
Chapters of the Washington Native Plant Society (WNPS) are located throughout the state and are excellent sources of information about species suited to various sites and maintenance objectives, sources of plant material, and plant establishment techniques. WNPS members may be willing to participate in volunteer projects that focus on planting and maintaining native plants.

When WSDOT chooses native plant species for roadside restoration projects, seeds or cuttings collected from areas near proposed planting are preferred propagation material because they have developed adaptations to the conditions of that area and provide the best possible contribution towards conserving the gene pools of local populations of native plants.

Manipulation of Natural Plant Succession Processes

The general strategy of manipulating succession may also be used to establish stable communities along roadsides. Tactics include very selective removal of undesired species, efforts to minimize community disturbance, and efforts to reintroduce key desirable species which may not naturally regenerate on the site. In order to develop treatments for converting vegetation at a site from an ecologically unstable condition to a relatively stable community of preferred plant species, it is important to understand natural plant succession processes as they occur on roadsides.

If left undisturbed, plant communities evolve slowly over time in a predictable process known as plant succession. This concept was documented by Clements (1916) and is illustrated in **Figure 5-2**. Unlike undisturbed areas, however, the roadside vegetation succession process occurs in many fits and starts, depending on the degree and frequency of soil disturbance. Construction many times leaves vegetation to develop on unamended cut or fill slopes; routine mowing, spraying, grading, or other soil disturbances often keep the successional process at a very early stage where weedy vegetation like thistles, ragwort, knapweed, horsetail and annual grasses have the competitive edge. Where soil disturbance is minimized, the cycle of growth and decomposition of these early-successional plants gradually improves soil conditions enough that the competitive edge shifts to perennial grasses, forbs (wildflowers), shrubs, and trees. Eventually a "climax" vegetation develops that can remain quite stable for many years so long as soil disturbance is absent or kept to a minimum. Whether the climax vegetation is dominated by trees, shrubs, forbs, or grasses depends on many ecological factors at a given location.



Vegetation Zones of Washington

Figure 5-1

By understanding the dynamics of plant succession, vegetation managers can design maintenance treatments to keep the plant community at the stage in the successional process most appropriate to meet the functional objectives at a given site and resist invasion by unwanted plants. The key to understanding this process is knowing the sources and locations of potential invading plant species and the competitive interactions among species (del Moral 1979).

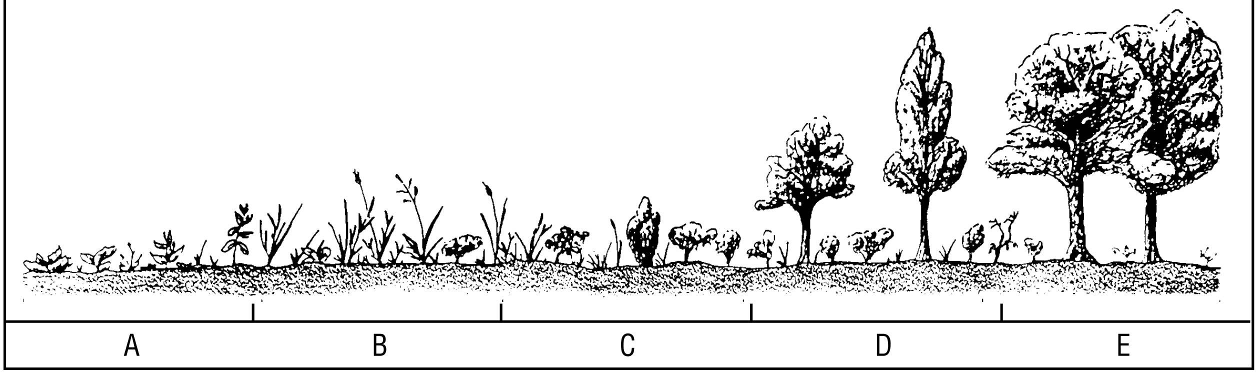
When using plant succession principles to plan maintenance activities, it is important to know that many roadside sites not disturbed by cut or fill operations already contained climax vegetation before they were cleared for road construction (Daar 1991). Thus, even though what is growing at a site appears to be early stage broadleaf weeds and annual grasses, there may be a seed bank in the soil representing all the successional stages (from pioneering annual weeds through climax trees), and these seeds can remain dormant but viable for many decades. This explains why discontinuing use of herbicides to maintain vegetation-free roadside zones can in some areas result in an immediate invasion of trees and shrubs in addition to herbaceous weeds (see **Box 5-B**). **Box 5-C** provides an historical example of the application of the principles of natural succession to vegetation management on rights of way.

Example: In coastal western Washington, the vegetation management objective for Zone 3, might be to develop a stable climax vegetation dominated by native trees and shrubs. If undesirable vegetation in Zone 3 required treatment, tactics that minimized soil disturbance would be emphasized in treatment decisions. Thus, clumps of Scotch broom, Cytisus scoparius, or gorse, Ulex europaeus, could be manually removed with weed wrenches, mechanically removed by severing the stems at the root crown to prevent resprouting, or killed with a basal application of an herbicide and removed. Cleared areas could be filled in with seeds or seedlings of desired trees or shrubs collected at the site, and the young plants mulched with chipped residues of the weedy shrubs.

In Zone 2 at the same site, an earlier perennial grass/forb stage of that plant community might be more suited to the operation of the drainage ditches than the shrubs and trees desired in Zone 3. To keep the perennial grasses dominant in Zone 2, mowing treatments would be specified to be applied at heights of 12 to 14 inches and timed to insure the site always maintains sufficient grass/forb cover to shade out any woody plants that attempt to establish in the grassland.

Vegetation Succession

This drawing shows a simplified sequence of vegetation succession. At, A bare, low-nutrient soil is colonized by broad-leafed plants such as thistles and some grasses. As the plant die and decompose, enriching the soil, grasses predominate (B). As the soil is further enriched, woody shrubs begin to appear (C), followed by trees (D). Eventually, the trees become the predominant vegetation type (E), shading out most competing vegetation.



Vegetation Succession
Olkowski, et. al, 1991
Figure 5-2

Box 5-B. Plants that Colonize Disturbed Soils

When a soil disturbing practice such as routine use of soil-residual herbicides to maintain vegetation-free zones is discontinued, the soil seedbank is released to produce an invasion of deciduous trees and shrubs in addition to forbs and grasses. In western Washington, red alder, big-leaf maple, cottonwood, and willows are the primary pioneer tree invaders. Salmonberry, Himalayan blackberry, salal, and dogwoods are pioneer shrubs. Numerous broad-leaved forb species both native and exotic, desirable and undesirable, are also likely to colonize the site.

In eastern Washington, discontinuing chemical control in the higher precipitation Cascade Range and Okanagon Highlands Provinces will result in alder (tree and shrub species), cottonwood, willows, oceanspray, ninebark, and ceanothus invading the site. The much drier Shrub-steppe Vegetation Zones of the Columbia Basin and adjacent provinces would be invaded by sagebrush, rabbitbrush, and in some areas, bitterbrush. These species should be encouraged to dominate roadsides as they provide cover for small mammals and birds, but are rarely browsed on by livestock or deer. Thus, they do not encourage grazing by livestock or large mammals near roadsides as do crested wheatgrass and other forage grasses commonly planted on the right of way

Source: WSDOT EIS Appendix A (1993)

Box 5-C. Applying the Concept of Succession to Vegetation Management on Rights of Way

Plant ecologist Frank Egler was the first to recognize the utility of the concept of succession when he developed methods for establishing stable shrublands under power lines in the Eastern United States. Egler wanted to move the plant succession back from the tree-dominant stage to the shrub-dominant stage. But if the trees were clear-cut or broadcast sprayed with herbicides, there would be so much soil disturbance that the succession would be moved all the way back to the earliest stage dominated by weeds, leading to an endless seesaw effect rather than the stable shrublands he was seeking to maintain.

Egler knew that where power lines or road systems have been developed through climax landscapes, much of the plant succession is already present in the soil as seeds, seedlings, or shoot-producing roots at the time land is cleared for construction. Therefore, invading plants may not necessarily come from outside sources, but from the existing seed bank responding to soil disturbance. He writes, “Development through successive stages is then a matter of unfolding that which was determined at the start. [Herbaceous] weeds at first outgrow and overtop all others, but soon the perennial grasses become visually predominant. Eventually the coarse forbs take over, through which the shrubs, originally present, eventually make their way. Finally the trees, there from the start, overtop the other plants and kill them out or relegate them to an inferior status” (Egler 1953).

This understanding led Egler to develop selective plant removal treatments that have become key to creating stable plant communities to meet various maintenance objectives. In Egler’s case, he was working to prevent tall trees from growing under power lines by using the tactic of encouraging shrubs to dominate the site. He reasoned that if tree seeds were already present in the soil seed bank rather than outside invaders, they could be selectively root-killed with herbicides or manual methods when they germinated, leaving a relatively stable shrubland low enough not to endanger power lines, but tall and diverse enough to offer food and cover to wildlife, and visual amenities to hikers, motorists, and adjacent landowners. So long as large openings were not created in the dense shrub community (e.g., by blanket herbicide sprays, clear-cutting, etc.), shrubs would be able to out compete trees for many years, thereby significantly reducing maintenance costs.

Egler put this insight into practice along a demonstration right of way in Connecticut which remained in stable shrub cover for the 20 years that data was kept. Low-impact removal of occasional trees that germinated in the right of way was the only maintenance required. A 30-year study of this approach on a power line right of way in central Pennsylvania also confirmed the validity and cost-effectiveness of this method as well as its positive impacts on wildlife (Bramble et al. 1990; Bramble and Byrnes 1982). Egler’s strategy is also applicable to sites maintained by WSDOT.

Habitat Modification

This refers to modifying the growing conditions at a site to favor desirable vegetation and impede undesirable plants. Tactics include very selective removal of key undesirable species, regrading of slopes which contribute to the problem, altering soil conditions with soil amendments, and judicious use of supplemental watering. Another very important tactic which should be applied whenever possible during construction is stockpiling of topsoil. By spreading topsoil back over roadside cut and fill many of the previously growing native plants will reappear.

Example: Grasses such as perennial rye, Lolium perene, tall fescue, Festuca arundinacae, and red fescue, Festuca rubra, and forbs such as bracken fern, Pteridium auilinum, and sword fern, Polystichum munitum, contain allelopathic toxins that leach into the soil and prevent certain other plants from growing. After using the tactic of establishing allelopathic grasses or forbs in Zone 1 or 2, the soil habitat becomes less favorable to growth of woody plants such as alders (which can block sight lines at some locations) or broadleaf weeds such as mustard (which can become a fire hazard when it dies and dries out).

Enhancement of Ecosystem Diversity and Processes

The most stable ecosystems are those containing the greatest diversity of elements. Diversity enables the system to respond to various pressures without collapsing. Two principle tactics are used, planting mixtures of vegetation and accommodating compatible wildlife.

Plant Mixtures of Vegetation Species Instead of Monocultures

Example: A monoculture is a large-scale planting of a single species of plant. Monocultures contribute to ecosystem instability by allowing plant-damaging pests to multiply unchecked over large areas, as when English ivy, Hedera helix, is attacked by a foliar pathogen that quickly spreads throughout the entire planting. The weakened plants drop infected leaves, creating openings for weed growth. While planting large blocks of a single plant species has certain economies, the tactic of planting smaller blocks, separated by groups of other species, lessens risks from pest damage and weed invasion, as does planting a mix of species over a larger, continuous area.

Example: In eastern Washington where extensive cultivated agriculture has replaced large tracks of wildlife habitat, roadsides are major potential refuges for pheasants, quail, and other ground-nesting birds. However, the roadsides are primarily vegetated with monocultures of crested wheatgrass, Acrisatum sp., which grows well in harsh environments and has forage value for cattle, but does not provide particularly good food or shelter for wildlife. An alternative tactic would be to include crested wheatgrass as a smaller component within a mix of native grasses and also encourage native shrubs such as sage and bitterbrush which do not attract large mammals to forage near the roadside.

Accommodate Compatible Wildlife

Wildlife ranging from deer and foxes to birds, rodents, and insects utilize roadside vegetation for food, water, and shelter. Their behaviors and requirements need to be taken into account when managing roadside vegetation.

Example: Stands of native trees and shrubs such as alder, maple, elderberry, salmonberry, etc. are often targeted for removal from roadsides for various reasons. These species serve as cover and preferred browsing vegetation for deer and elk. When these plants are present in Zone 3, the animals tend to avoid the roadside and feed on the shrubs and trees. When the woody vegetation is clear-cut and replaced with grasses, the animals are more likely to browse near the roadbed where they are more vulnerable to vehicles. However, if the trees are growing too close to the roadbed, drivers may not have enough visibility to see deer and avoid them. Thus, where monitoring has shown deer are commonly seen, trees and shrubs should be encouraged in Zone 3, but lower vegetation should be grown in Zones 1 and 2. This combination of tactics will be particularly useful where historic migration routes of deer and elk are bisected by highways.

Human Behavior Changes

Most of the noxious weeds that appear on roadsides are imported into the area and spread as a result of human activities. A combination of education and regulation is needed to increase awareness about the role human activities play in generating vegetation problems and to gain cooperation in changing these behaviors to prevent future vegetation problems, particularly the spread of noxious weeds. WSDOT can work with county weed boards, county road agencies, regional and state parks, and private landowners to help curb the spread of noxious weeds. **Box 5-D** lists suggestions for increasing awareness and public participation in weed prevention. Education may also be needed to foster acceptance of new maintenance practices and resulting patterns of vegetation. Chapter 7, "Education and Outreach," will describe approaches to educating WSDOT personnel and the general public about the merits of an IVM program.

Weed Suppression Methods

These are the strategies most familiar to vegetation managers. They include:

- Biological Controls
- Chemical Controls
- Cultural Controls
- Manual Controls
- Mechanical Controls
- Physical Controls

All of these strategies involve direct control actions targeting one or more problem species. When using direct controls to manage undesirable vegetation, it is essential that they be combined with monitoring activities and methods that prevent weeds from returning. This integrated approach produces long term solutions and reduced costs.

Box 5-D. Reducing Spread of Weeds

An important component of an IVM program is preventing spread of weeds to new areas. Modification of human behaviors and land management practices are essential to achieve this goal and must be approached statewide in cooperation with other agencies and organizations. Preventive measures include the following:

- Establish a program to increase public awareness of weeds and the consequences of the careless use of natural resources (see Chapter 7 for more detail).
- Control roadside weeds to prevent vehicles from picking up and moving weeds.
- Restrict recreational vehicles to designated areas, and minimize recreational activities that result in excessive soil disturbance.
- Apply good livestock management, including an appropriate level of grazing, and advocate practices that prevent excessive soil disturbance and promote healthy, competitive vegetation stands resistant to weed establishment.
- For a period after grazing on a weed-infested site, confine livestock and clean animals of burs and seeds before moving them to a new area.
- Prevent weed movement in feed and seed by keeping pasture weed populations at low levels.
- Keep sand, gravel, and rock quarries free of weeds to prevent their dissemination with the material.
- Seed newly disturbed areas, such as roadsides and construction sites, with adapted, desirable plant species to provide a quick cover in which weeds cannot establish.

Adapted from Powell, et al. (1994).

Biological Controls

This strategy involves maximizing the impact of the pest vegetation’s natural enemies. These are primarily tiny predatory insects that feed on plant stems, flowers, seed heads, and roots. Rusts and other pathogens that attack plant foliage are also available as biological control agents. Sterile carp can be used to control aquatic weeds, and goats and sheep are used to clear fire trails and control exotic vegetation on forests, parklands, pastures, and roadsides.

Insects and Pathogens

Virtually all insects and pathogens (primarily fungi) used as biological control agents against pest vegetation are host-specific. That is, they are only able to feed and reproduce on one plant species or a few closely related species within one plant genus and only on one part of the plant (i.e., only the foliage, or the seed head, etc.). This is important because it makes it virtually impossible that natural enemies released to control a specific species of plant will attack agricultural crops or other beneficial plants when their target food source runs out. Instead, they die off.

Example: The larvae of a tiny predatory fly, Urophora affinis, feeds only on the seedheads of several species of knapweed in the genus Centaurea. These include brown knapweed, Centaurea debauxii, diffuse knapweed, C. diffusa, and spotted knapweed, C. maculosa. If seed heads are not available, the fly cannot feed or reproduce on any other part of the knapweed plant, or on any other plant genera.

Virtually all of the most difficult to control weeds in Washington State were accidentally imported into the United States from other countries. Most arrived without their natural enemies, which is one of the reasons they are such successful competitors and prolific reproducers. Many of these introduced plants are listed as noxious weeds by the Washington State Noxious Weed Control Board. A list of these noxious weeds is included in **Appendix 8**.

For over a century, scientists from the United States Department of Agriculture (USDA) have searched the countries of origin of introduced weeds for natural enemies to control these plants. Importation of natural enemies into the United States is done by highly specialized personnel in approved USDA laboratories. Importation permits must be obtained from the USDA and the live insects or pathogens sent through a USDA-supervised quarantine laboratory which observes a strict protocol to avoid the introduction of undesired organisms.

Candidate biological control organisms are exhaustively studied to ensure that the natural enemy will attack only the targeted weed and not other vegetation. If this is successfully demonstrated, the natural enemy is mass reared in laboratories and tested in the field. If the biological control agent is able to establish and is effective at suppressing the target weeds, it is made available for widespread release through a permit process administered by the USDA.

There are three general tactics used in biological weed control projects in Washington State:

- Classical biological control
- Inundative releases
- Conservation of natural enemies

Classical biological control uses natural enemies to reduce weed populations to very low levels. The goal is not to eliminate the weed, but rather to obtain a long-term balance between weeds and natural enemies that enables the natural enemy to survive and remain available to provide continual and self-perpetuating suppression of the weed. This approach recognizes that seeds of target weeds are repeatedly reintroduced into roadside locations and provides a force of low-cost biological control agents that continually search for their host weeds.

Inundative biological control uses mass releases of natural enemies to attempt to eliminate a weed from an area; however, this approach does not address the residual seedbank in the soil or reintroduction of the weed at a later date.

Conservation of natural enemies already established involves protecting these organisms from herbicide sprays and destruction of habitat. *This includes tolerating the presence of low populations of target weeds in order to keep natural enemies alive.* When using herbicides in the vicinity of biological control sites, the following precautions will help conserve natural enemies of weeds:

- Choose the most selective, least toxic material and application method
- Treat only if action levels have been reached
- Spot-treat to reduce impact on nontarget organisms
- Time treatments to be least disruptive in the life cycles of the natural enemies

Mechanisms of Biological Control

While some natural enemies directly kill weeds by feeding on them, they more frequently reduce weed populations by stressing them and reducing their vigor and reproductive ability. This allows desirable vegetation to compete successfully against the weeds. While a single natural enemy species can successfully suppress a weed population (e.g., the klamath beetle, *Chrysolina quadrigemina,* which restored millions of acres of rangeland infested with St. Johnswort, *Hypericum* spp., to productive use), it is generally more effective to use several different organisms that attack different parts of the plant.

Example: A moth, a flea beetle, and a fly attack different parts of tansy ragwort, Senecio jacobaea. *The larval stage of the cinnabar moth,* Tyria jacobaea, *feeds on leaves and stems; adult ragwort flea beetles,* Longitarsus jacobaeae, *feed on leaves while their larvae feed on roots; the larval stage of a predatory fly,* Hylemya seneciella, *feeds on seed heads. This combination of biological control agents has provided good control of tansy ragwort in Washington, Oregon, and California. In Oregon, the benefit to cost ratio of the biological control program is estimated at 13:1 to 15:1, with benefits currently valued at $5 million per year (Isaacson and Radtke 1993).*

Biological control organisms take several years to become established in an area and build up populations large enough to seriously impact the target plants. They will not work in every situation because the habitat in which they are released may not be suited to their needs. Patience is required in the early stages of a biological control program because the process may be slow initially, but once in place, it is permanent.

WSDOT Biological Control Programs

WSDOT has initiated biological control programs in some areas against tansy ragwort, St. Johnswort, knapweeds, rush skeletonweed, Canada thistle, and Scotch broom. Effective population reduction of tansy ragwort, St. Johnswort, and rush skeletonweed has been achieved in areas where the insects have become established, and collection and distribution of these natural enemies to other areas of weed infestation should continue. Biological control agents released against the other weeds have not yet proven effective, although some plant damage has occurred. WSDOT support for further efforts to locate and test potential biological control agents for these and other weeds should be encouraged.

A number of the most widespread noxious weeds in Washington State have biological control agents which are available for release from government or commercial sources. These biocontrol agents, the weeds they attack, and sources of the natural enemies are described in the *Field Guide to the Biological Control of Weeds in British Columbia* discussed in **Appendix 9.**

Chemical Controls

The application of herbicides is used to remove or retard vegetation growth on road shoulders, ditches, and rights of way. Herbicides are best used to improve the potential for success of desirable vegetation, and will be used more in the early stages of an IVM program implementation. As desirable or tolerable vegetation becomes established, problem vegetation is naturally suppressed or precluded. The only place where chemical controls should be needed on a regular basis is where a Roadside Management Zone 1 devoid of vegetation is necessary to serve the functional objectives of the roadway or occasional spot treatment where new problems emerge.

Herbicide usage requires a large investment in planning for proper chemical selection, application rate, timing with phenology of target and nontarget species, site-specific environmental constraints, and planning for the safety of applicators and all potential off-site recipients of residues.

Types of Herbicides

Herbicides used by WSDOT range from nonselective pre- and post-emergence soil treatments to highly selective foliar-applied chemicals that target relatively narrow groups of broad-leaved forbs, shrubs, and trees.

Where desirable vegetation is established on slopes and medians, spot treatments of individual plants or small, localized populations with selective herbicides are very effective for maintaining and enhancing the growth of grasses and coniferous trees and shrubs. If desirable vegetation has not been previously established, applications of nonselective, nonresidual herbicides generally results in rapid reinvasion by weedy species, necessitating additional treatments in the future. **Box 5-E** discusses this and other consequences of herbicide use.

Cultural Controls

The term *cultural controls* refers to modifying planting and maintenance activities to promote vigorous beneficial vegetation that can out-compete weeds. Tactics include:

- managing the soil seedbank
- fertilization
- allelopathy
- mulches
- modification of soil pH

Box 5-E. Impacts of Herbicide Use

The impacts of chemical treatments vary depending on how closely the target and nontarget species are related, the selectivity of the herbicide, and the application method, timing, and rate. Populations of annual plants are generally more sensitive to herbicides than are perennials, especially if treated before producing seed. Annual and perennial weed species that have been established at a site for a few years often have large seed reserves in the upper soil horizons and will require repeated treatments. Annual re-treatment may be required until the majority of weed seeds have germinated and been killed, and highly competitive, desirable vegetation has become established on the site.

Although often the lowest cost treatment in terms of annual labor, materials, and equipment, chemical control of vegetation also sometimes results in high environmental costs and may also have a higher cost of the life cycle of the roadside, (see "Criteria for Selecting Treatments," later in this chapter, for other costs associated with chemical control). Rainfall following herbicide applications or windy conditions causing drift during herbicide applications along road edge, ditch, and backslopes may result in residue contamination of stormwater runoff and nontarget areas. Poorly planned or executed herbicide applications often remove or damage both desirable and undesirable vegetation. It is important that WSDOT continue its efforts to prevent the misapplication of herbicides and keep any negative impacts of herbicide application to a minimum. Removal of all vegetation with nonselective herbicides creates sites for accelerated soil erosion and invasion by undesirable plant species. This practice should only be conducted when areas are to be promptly reseeded and properly mulched.

Managing the Soil Seedbank

Before installing new plantings, it is important to reduce potential undesirable vegetation in the existing soil seedbank.

Example: Soil can be disked or rototilled, and subsequent irrigation (or rainfall) will germinate weed seeds. Once weeds have germinated, they can be killed by shallow tillage, flaming, or spot-treatment with a contact herbicide. Planting of desirable species can follow.

Example: When planting large acreage of grasses, range drills can be used even on very rough terrain to drill seed into the soil with minimal seedbed disturbance.

Fertilization

Careful application of moderate levels of slow-acting fertilizers can help stimulate growth of desirable vegetation. It is important to avoid heavy application of soluble nitrate fertilizers that can pollute surface and groundwater and stimulate weak, succulent plant growth susceptible to attack by pest insects, mites, and pathogens.

Example: When problematic brush has been selectively removed from a stand of desirable shrubs, spot applications of foliar or soil-applied fertilizer to shrubs will encourage them to fill in the bare areas.

Example: When planting large stands of grasses or wildflowers, fertilization with slow-release fertilizers containing higher amounts of phosphorous than nitrogen will stimulate flowering and strong root systems.

Allelopathy

The term *allelopathy* refers to the ability of certain plants to produce toxic substances that become incorporated into the soil and inhibit the growth of certain other plants (see **Figure 5-3**). Plants found on Washington roadsides that exhibit this property include grasses such as perennial rye, *Lolium perene,* tall fescue, *Festuca arundinacae*, and red fescue, *Festuca rubra,* and forbs such as bracken fern, *Pteridium auilinum,* and sword fern, *Polystichum minutum.* (Larson and Schwartz 1980; Peters and Zam 1981; Rice 1972). By planting moderate to low-growing allelopathic species in areas where sight lines must be maintained, trees such as maple, alder, etc. can often be stunted or prevented from growing.

Mulching and Erosion Control

Mulching involves covering bare soil with organic or inorganic materials to block emergence of weeds and conserve soil moisture. Mulch can also help prevent erosion, thus increasing the likelihood that plantings of beneficial vegetation on slopes will survive and become established. Mulches can be combined with geotextile materials that secure slopes from mass erosion by adding cohesive strength. Other advantages of mulches include:

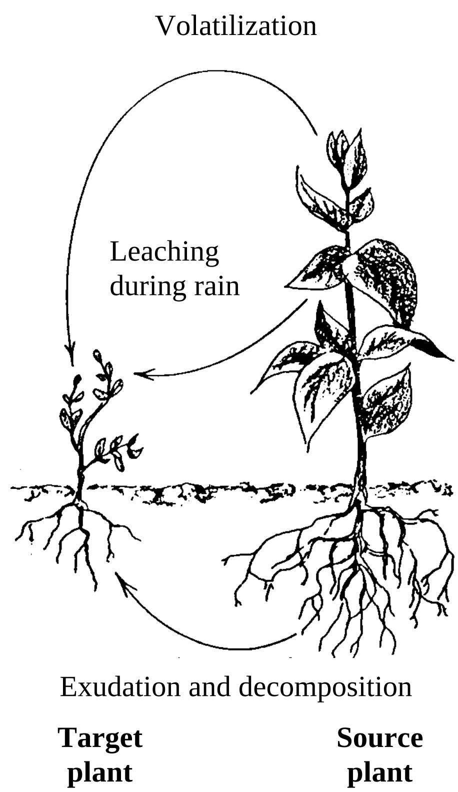
- Absorption and dissipation of energy released by falling rain
- Reduction of runoff water velocity
- Moderation of weather conditions including soil temperature
- Securing soil and materials in place
- Promotion of sod and wildflower development through decomposing mulch
- Enhancement of appearance of developing landscapes

Tactics include use of *organic and inorganic mulches.* Organic mulches include chipped materials, shredded bark, and composted materials. Inorganic mulches include fabric weed mats, black plastic, and crushed rock (which scatters less than riverrun rock).

To be effective as a weed control treatment, organic mulches must be applied at a minimum depth of 3 to 6 inches shortly after plantings have been installed. Replacement at two- to three-year intervals is usually needed due to decomposition and movement off-site by water or wind. Inorganic mulches such as weed fabric that contain UV inhibitors will last five years or longer but will not provide the benefit of soil conditioning created by decomposing organic mulches.

Allelopathy

Some plants exude toxic substances that inhibit the growth of competing vegetation, a phenomenon known as allelopathy. The source plant releases toxins that vaporize in the air, leach into the soil in rainwater or are exuded from roots or decomposing tissue. Nearby seeds or plants that are susceptible either fail to germinate or are stunted or killed after contact.



Allelopathy

Aldrich, R. J., 1994

Figure 5-3

Landscape weed fabric is the most effective inorganic mulch. As a treatment, it is either placed on the soil and desirable vegetation is planted through slits in the fabric, or the fabric is placed on the soil between already planted vegetation. The fabric blocks sunlight from reaching germinating weed seeds but permits exchange of water and air in the root zone of desirable plants. Although most products contain UV inhibitors, it is best to cover the fabric with organic mulch or crushed rock to enhance aesthetics and protect the fabric from sunlight and wind. The weed fabric is most cost effective when used in intensively landscaped areas such as medians and interchanges in urban areas. Black plastic is not recommended for use on roadsides due to its rapid photodegradability and unsightly shredding.

Modification of Soil pH

In some cases, modification of soil pH may help suppress a target plant species and promote beneficial vegetation. Spot-treatments in pavement cracks or along fence and guardrail lines may be effective in practice. Usually, soil pH is raised through application of a source of calcium such as lime, gypsum, or crushed shells to the soil surface. Managers should be aware that other problem plants may colonize the newly created area of high pH soil. This tactic should be tested on a site before widespread use can be recommended.

Example: Applying lime in a band near the pavement edge may suppress horsetail, Equisetum *spp., where patches are encroaching on the roadside.*

Manual Control

Manual control tactics are used to selectively remove vegetation in areas where mechanical or other methods are not practical (e.g., close to guardrails, tree trunks, etc.). Hand-carried tools and power equipment are generally used in manual control, although hand-pulling is sometimes appropriate. Manual control tactics include:

- Hand pulling and grubbing
- Manual cutting

Hand Pulling and Grubbing

This tactic employs hand-carried tools and equipment to remove unwanted vegetation. It is primarily used in landscaped areas, drainage ditches, or sensitive areas such as wetland mitigation where unwanted plants are scattered within stands of desirable vegetation. Shovels, hoes, pulaskis, mattocks, or weed wrenches are typically used to remove weeds. Special attention is paid to removing the root system of weeds to prevent regrowth.

Example: Scotch broom, gorse, alders, and other brush with stem diameters 2.5 inches or less can be quickly and easily removed with a weed wrench. By placing the steel jaws around the plant stem and pumping the lever arm, the plant is uprooted with minimal disturbance of soil or surrounding plants. The tool is most effective when soils are moist or loose.

Manual Cutting

Both woody and herbaceous plants can be cut with a variety of tools. Chainsaws, handsaws, axes, and pruning tools are used to cut trunks and limbs of large trees and shrubs. Small shrubs and tall-growing herbaceous plants can be cut with small power mowers, string cutters (using strings or blades), machetes, scythes, and weed whips.

Manual cutting is used to selectively remove unwanted trees or limbs to preserve sight lines, prevent ice on roads, provide vehicular clearance, etc. Cutting is also used to clear brush and herbaceous weeds away from culverts, drainage ditches, or other structures. In addition to training in safe use of power equipment, maintenance crews should be provided with treatment details such as how, when, and where on the target plant to place the cuts to prevent decay of standing trees or to minimize resprouting of stems on unwanted trees or brush.

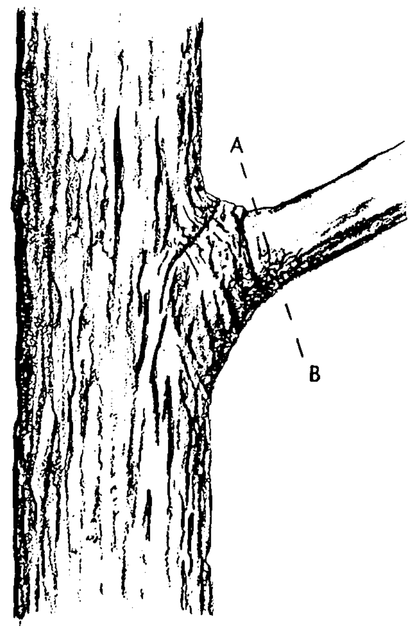
Example: When removing limbs from trees in order to provide vehicle clearance, etc., proper placement of the cut is an essential treatment detail for promoting rapid healing of the wound. Limbs should be cut just to the outside of the branch collar — a swollen collar of wood located at the point where the branch grows out of its supporting limb or trunk (see ***Figure 5-4*)*. When a tree is wounded by removal of a limb or branch, tissues in this collar form the chemical barriers that wall off decay organisms and stimulate healing of the wound (Shigo 1986). Cutting a branch off too close to the parent trunk or limb removes the branch collar and leaves the tree vulnerable to decay organisms. By the same token, leaving a stub 6 inches or longer when removing a branch impedes the formation of protective barriers to decay.*

Example: Conifers such as Douglas fir generally do not resprout after being cut down. However, most hardwood trees and woody shrubs such as alders, Scotch broom, gorse, etc., respond to cutting of their trunks or stems by vigorously resprouting from the roots or root crown (the point where stem and root meet). Resprouting by alder and broom can be prevented or reduced with proper timing and placement of the cuts.

Alder that is at least four years old (minimum 2-inch diameter stem) can be killed by cutting it at the proper time of year. The prime window of vulnerability is approximately three months after budbreak (this generally occurs during the month of July in Washington State), although the exact timing for peak mortality varies from site to site (Prull 1989) which is illustrated in ***Figure 5-5****. Optimal timing of cutting can be determined by monitoring experimental plots in various regions and recording the data for future reference. An optimal time for cutting Scotch broom,* Cytisus scoparius, *has not been established, although cutting it during or shortly after the bud stage is recommended to prevent seed production. Broom plants at least four to five years of age will not resprout following cutting.*

The Shigo Pruning Technique

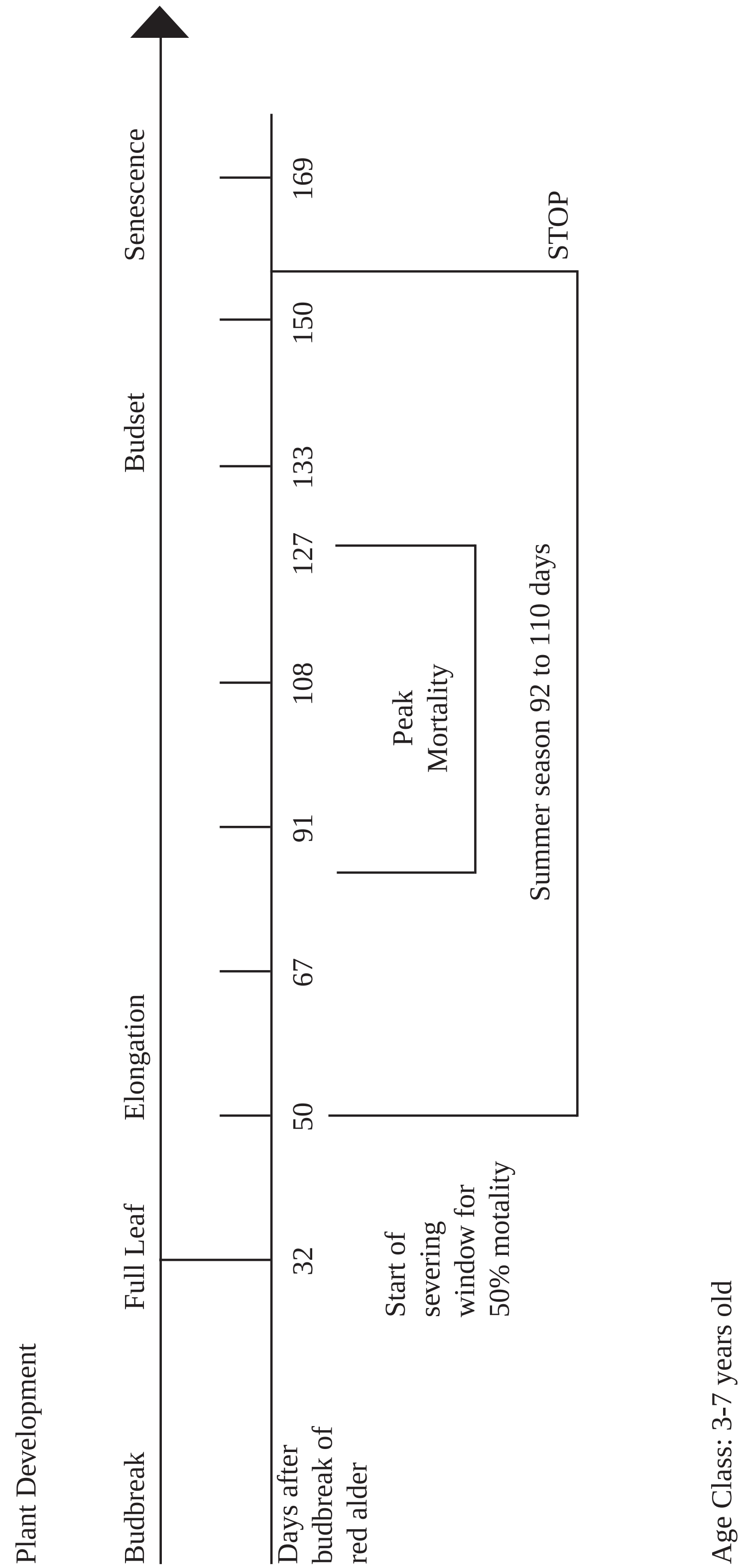
To minimize access of decay organisms to pruning wounds in trees, cut living and dying branches as close as possible to the branch collar, as indicated by line A-B. Do not leave stubs, and do not paint the cuts.



Effective Pruning Technique for Trees

Shigo, A., 1986

Figure 5-4



Timing Red Alder Cutting to Prevent Resprouting

Prull, G., 1989

Figure 5-5

When cutting alders, broom, etc., cuts should be made at the root crown (where roots branch out from the stem). It may be necessary to grub away soil to expose the root crown for cutting. Higher cuts on the stem generally result in resprouting. Note: alders or other woody plants that have been repeatedly mowed and resprouted into dense clumps generally cannot be killed by the technique described above. Removal of the clump with a backhoe or a combination of cutting and stump-treatment with an herbicide is generally effective in these situations.

Mechanical Control

Mechanical control tactics utilize motorized equipment to remove or suppress unwanted vegetation. These tactics include:

- Mowing
- Brush cutting and crushing
- Grading and blading
- Disking
- Chipping
- Seeding

Mowing

Tractor-mounted sickle bars, flails, or rotary mowers are used to mow grasses, forbs, and small-diameter trees and shrubs on roadsides. Hard-to-reach areas such as ditchbanks, or steep-cut slopes are mowed with specialized flail mowers whose cutting heads are mounted on hydraulic arms. Heavy-duty brush cutters are used to grind up tree limbs and trunks up to 6 inches in diameter and mulch the debris. The cutting deck can be raised to a height of up to 2 feet, allowing low-growing vegetation to survive. Some mower models mulch debris, which speeds decomposition, and eliminates the need for off-site disposal.

Depending on how it is used, mowing can either enhance or interfere with long-term solutions to unwanted vegetation. Knowing the appropriate mowing height, timing, and number of mowings per season needed to promote desired vegetation and suppress unwanted plants are essential treatment details for insuring long-term success with mowing. Thus, the person on the mower needs to be aware of the impact of mowing on beneficial plants as well as on unwanted vegetation.

Example: If the objective is to promote growth of grasses and discourage shrubs or trees from growing in Zone 1 or 2, the mowing height should be raised to 12 inches or higher in order to reduce stress on grass from mowing and to maintain sufficient shade at the soil level to discourage germination of woody plant seeds.

Example: In eastern Washington where annual grasses and forbs die and dry up in early summer, it is most effective to wait until plants have finished their growth cycle before mowing. If mowing occurs earlier, annual plants can often regenerate, requiring additional mowings. If there are weedy annuals invading the desirable grasses and forbs, spot-treat the weeds with a weed-whip when they are in the bud stage, allowing the desired vegetation to set seed before the entire area is mowed.

Example: In dry areas of the state where summer fire hazards are of concern, it is desirable to plant the roadside with drought-tolerant perennial grasses that remain greener longer into the fire season than annual grasses. When establishing perennial grasses, timing of mowing is critical to reduce competition by annual grasses and forbs. Mow the faster-growing annual plants in late spring when they are taller than the slower-growing perennials but have not yet set seed. Several carefully timed mowings may be required the first season to reduce competition from spring and summer annuals. After two seasons of this mowing regime, the perennials will have the competitive edge over the annuals.

Example: The ability of desirable low-growing perennial shrubs like salal, Galultheria shallon, *to resprout can be used to advantage in a mowing program. Mowing over several years at the appropriate height of 8 to 12 inches will encourage the salal to spread and dominate a site. To achieve this objective, mowing should occur before salal reaches the bud stage and still has stored food reserves in its roots to use for resprouting.*

Grading and Clearing

Graders and backhoes are used for nonselective clearing of vegetation. Blades on graders are primarily used to scrape vegetation from Zone 1 in the process of reshaping the soil surface and restoring lateral support by replacing soil eroded from road shoulder. Road shoulders are graded to improve drainage, and vegetation is removed during this process. Backhoes are used to clear vegetation from culvert inlets and outlets and drainage ditches, as well as from other locations on the rights of way.

These activities severely disturb the soil, and the end product is bare soil ripe for weed invasion and erosion. When grading activities are scheduled, treatments for revegetating, paving, or otherwise covering the soil should also be scheduled to follow grading activities in order to prevent weed problems from occurring.

Disking

Disks are tractor-pulled cultivators that slice through and turn over soil. They are used to clear vegetation for fuel breaks along fencelines and roadside boundaries, as well as for preparing seedbeds for roadside plantings. Disking creates bare soil susceptible to erosion and weed invasion. These problems need to be taken into account when disking is scheduled. Revegetation or mulching treatments should always be planned to follow disking activities

Chipping

Machines that grind up shrubs or tree limbs under 6 inches in diameter are used to recycle plant debris as mulch on roadsides and thereby reduce off-site disposal costs. WSDOT already employs chippers as well as track and spyder-mounted mulching machinery to chip woody materials. Mulch from chipping may be used on-site to help suppress noxious weeds or be transported to another area where managers wish to apply organic mulch as a control tactic.

Seeding

Range seed drills and cultipackers are used to drill in seed and firm the soil surface to insure good seed/soil contact when planting competitive vegetation. Range seed drills can be used on rough or gentle terrain with minimum disturbance to the soil.

If a drill is not available, broadcast seeding by hand or with a bellygrinder can be used to apply seed, but only where a seedbed is already prepared by removing existing vegetation. After broadcasting the seed, it must be worked into the soil by hand or with an implement such as a harrow made of chain link fence and pulled behind a truck or tractor. Newly seeded areas should be monitored frequently to determine if supplemental watering, fertilization, or weed suppression is needed. Managers should consult the department horticulturist for information on what treatments newly seeded plants will need to successfully establish.

Physical Control

This strategy uses barriers and thermal control methods to prevent or suppress unwanted vegetation. Tactics include:

- Barriers
- Controlled burns
- Flaming
- Hot water

Barriers

Physical barriers such as soil cement or other paving material can prevent weed growth in landscaped areas or around guardrails, poles, and other structures. These types of treatments block the sunlight required for germinating weed seeds to survive.

Soil cement is an inexpensive paving material created by incorporating dry Portland cement into soil and wetting it to form a barrier (Appleton 1993). This or other paving materials such as asphalt can be used to form permanent weed barriers around sign poles, guard rails, and other roadside structures.

Controlled Burns

Burning brush to promote growth of grasses and forbs is an age-old technique. Currently, controlled burns are used in forests and parklands to reduce accumulated ground litter and suppress fire-hazard brush such as Scotch broom and gorse. In some agricultural areas the tactic is used to burn off stubble, and clear weeds from irrigation ditches and field edges. In midwestern states, periodic controlled burns in late spring or early fall are used by state and county road departments to remove weedy vegetation and help reestablish perennial prairie grasses and wildflowers along roadsides.

In eastern Washington where the native vegetation has coevolved with wildfires, properly timed roadside burns can be useful in reducing invasive weeds and promoting desirable native shrubs, grasses, and forbs. However, air pollution regulations, hazards from smoke obstructing highway visibility, difficulty of preventing fire escapes off roadsides, and objections from adjacent landowners will have to be addressed if this technique is proposed. If controlled burns are used, it is critical that they be timed to promote desired vegetation, and that appropriate follow-up treatments such as seeding, replanting, and fertilization are applied to prevent weedy vegetation from colonizing the bare soil.

Flaming

This tactic involves using hand-held or tractor-mounted torches to heat the cell sap of vegetation sufficiently (i.e., to 2,000°F) to rupture plant cells causing the treated plant to wilt and die. Plants are treated when they are green by passing the torch slowly over plant at a height of 4 to 6 inches. The torch should *not* be held for long periods on the plant and there should be no combustion of plant material. Leaves that have been heated sufficiently to burst cell walls will feel very soft to the touch and may turn a purplish color before wilting and dying. Plants die within 24 hours. Weed seeds at or near the soil surface are also killed by flaming.

The technique is most effective on broadleaf weeds in the seedling (four- to five-leaf) stage because at that point the fragile root system is killed along with the top growth. Mature perennial weeds such as Canada thistle, *Cirsium arvense*, and morningglory, *Convolvulus arvensis,* also succumb to flaming, but only after a number of treatments spread over a season or two. Grasses are less susceptible to flaming because they have protected growing points that enable them to regenerate after treatment. This can be used to advantage where grasses are the desired vegetation but are under severe competition from broadleaf weeds. The entire planting can be flamed, and the grasses will recover.

Hand-held flamers are useful as both broadcast and spot-treatment tools in landscaped areas. Before seed or transplanting and after soil has been prepared, hand-held flamers can be used to knock down germinating weed seedlings without disturbing the soil and bringing new weed seeds within germination range (top 2 inches of soil). They also can be used to *spot-treat* young weeds growing among established plants.

Tractor mounted flamers could be useful in roadside revegetation programs to control early germinating broadleaf weeds that compete with later-germinating perennial grasses. Since flamers do not open the soil as does tillage equipment, buried weed seeds are not triggered into growth. Plants killed by flaming provide small amounts of mulch that quickly decays, returning nutrients to the soil.

Flaming has a long history of use for weed control in orchards, cotton and alfalfa, and tractor-mounted equipment is available from agricultural suppliers. Hand-held flame equipment used in forestry and road repair can also be used on roadside vegetation. Flamers designed for use in parks and landscaped areas are available from horticultural suppliers.

Hot Water

Machines that use superheated water to kill weedy vegetation are being used in Europe, Australia, and New Zealand, and are becoming available in the United States (Daar 1994). Water is pumped under pressure through a heated chamber onto weeds. The combination of heat, pressure, and water volume breaks down cellular structure, causing discoloration and death within hours or a few days. One treatment kills most annual weeds and young perennials. Top growth of older perennials can be killed in one or two treatments, but impact on roots may be minimal unless repeated kill of top growth is employed to starve roots of nutrients. Hot water equipment sized for roadside applications is being field tested in the United States, and is expected to reach the market in 1996.

Selecting and Applying Treatments

Once it has been determined that a treatment is needed in one of the *focus areas* where monitoring efforts have been concentrated, the manager must specify one or more treatments. In some cases, WSDOT policy may recommend specific tactics or treatments over all others. In other cases, the manager will have more options to consider and may wish to consult the department horticulturist.

The process of specifying treatments should be based on a set of criteria for treatment selection. The manager must specify or choose a treatment which will:

- Achieve *vegetation management objectives* for the *focus area*
- Possess the best available combination of optimal treatment characteristics

Defining Management Objectives

When selecting treatments, it is important to carefully consider the *vegetation management objectives* for the area. *Vegetation Management objectives* are the specific work goals set by managers to achieve the *functional zone objectives* and *environmental objectives* set by WSDOT policy. In addition to functional and environmental objectives, the WSDOT Vegetation Management Program is guided by a number of *overall objectives* which influence the process of determining management objectives and specifying treatments. **Box 5-F** summarizes WSDOT functional zone objectives, environmental objectives and overall objectives and provides examples of specific management objectives derived from them.

Box 5-F. Understanding WSDOT's Overall Vegetation Management Objectives

Understanding the relationship between daily maintenance activities and the objectives of the Vegetation Management Program is vital to effective management. Vegetation does not become a problem until it interferes with the functioning of the system in some way. Typically, a given area of roadside will have vegetation which impacts some of the WSDOT functional or environmental objectives, but not all of them. Managers must identify which objectives are compromised and how the vegetation is interfering before treatments can be determined and applied successfully.

Overall Objectives

These are the guiding principles which shape the Vegetation Management Program. They include:

- Provide safe and reliable transportation
- Preserve the investment, lower life cycle costs
- Support commerce and economic viability
- Comply with legal mandates
- Be a responsible member of the community

- Be environmentally responsible
- Contribute to a positive appearance

The first two overall objectives are divided into *functional zone objectives* and *environmental objectives*, set by WSDOT policy and standards and applied statewide. The third, fourth, and fifth overall objectives guide the general thrust of management and maintenance activities and accommodate special statewide management needs such as noxious weed suppression. The last two overall objectives ensure that WSDOT maintenance staff remain responsive to the needs of citizens and institutions who's land holdings are impacted by vegetation management activities. WSDOT has decided that maintenance activities should focus on preventative, rather than reactionary approaches to minimize costs and maximize benefits. *Establishment of persistent communities of desirable vegetation offers the best opportunity for effectively and efficiently achieving all seven overall objectives for the WSDOT Vegetation Management Program.*

Functional Zone Objectives

These are the specific objectives, as determined by WSDOT policy and local needs, which relate to operational aspects and desired outcomes from roadside vegetation management activities. Chapter 7 of the WSDOT *Pocket Roadside Manual* defines the departments functional objectives and identifies which roadside zones they apply to. Functional objectives will tend to remain the same over time and apply equally to a wide variety of roadside areas, but not every site will need to be managed for all functional objectives. WSDOT Functional Zone Objectives for vegetation management are:

- To maintain conditions for rapid drainage of water from the roadway surface (Zone 1)
- To minimize fire hazards (Zone 1)
- To prevent vegetation from causing damage to pavement and roadside structures (Zones 1 and 2)
- To maintain adequate site distance along curves and at intersections (Zones 1 and 2)
- To maintain good visibility of and for pedestrians and animals (Zones 1 and 2)
- To maintain good visibility of regulatory and advisory signs (Zone 2)
- To minimize headlight glare hazards (Zone 2)
- To minimize treefall hazards (Zone 2)
- To minimize ice formation hazards (Zone 2)
- To accommodate utilities (Zone 3)
- To provide a transition between the roadway and adjacent lands (Zone 3)
- To respond to the needs of neighboring landowners to the extent consistent with other functional and environmental objectives and WSDOT policy and procedure (Zone 3)

Environmental Objectives

These are the specific objectives, as determined by WSDOT policy, for *minimizing environmental impact* of maintenance activities. Some apply to all zones while others apply to Zones 2 and 3 only. The environmental objectives are:

- To control erosion (all Zones)
- To control noxious and troublesome weeds (all Zones)
- To protect and enhance sensitive environmental resources such as water and wetlands, and rare or endangered plant and animal species (all Zones)
- To protect and enhance cultural resources such as landmarks and historic sites (all Zones)
- To protect and enhance aesthetic values (all Zones)
- To provide wildlife habitat to an extent that does not compromise safe mobility (Zones 2 and 3)
- To preserve wetlands (Zones 2 and 3)
- To protect and restore native vegetation (Zones 2 and 3)

Vegetation Management Objectives

These are the specific objectives or goals, set by area managers for achieving *functional* and *environmental* objectives through daily maintenance activities. Vegetation management objectives translate the general statements of functional and environmental objectives into specific goals tailored to a particular situation and the capabilities of maintenance staff. *Treatments* are the actions taken to achieve vegetation management objectives.

Putting It All Together

Consideration of *overall*, *functional* and *environmental* objectives leads to the development of *vegetation management objectives* for a given site. These objectives are realized when *treatments* are specified and then applied.

Example: A stretch of road contains slopes where stands of gorse, Ulex europaeus, *are causing concern because of their high flammability potential. The vegetation management objectives are established to meet the relevant functional and environmental objectives for Zone 2 and 3 at these sites.*

- **Functional Objective:** Minimize fire risk.
- **Environmental Objective:** Prevent erosion.
- **Vegetation Management Objective:** Replace gorse with low-flammable, fast-growing vegetation that prevents erosion and re-invasion of gorse.
- **Treatment:** Use low-impact tactics to minimize soil disturbance and prevent erosion when removing gorse. These might include manual removal with a weed wrench, mechanical removal by cutting at the basal crown prior to seed formation, or injection with a translocating herbicide followed by cutting and removal of the dead crown. Mowing is not an appropriate tactic in this situation because it promotes stump-sprouting of the gorse which increases the size of the gorse stand over time. Removal of gorse is followed by seeding the cleared

area with a mixture of fast-growing annual grasses to prevent erosion, and low-growing perennial grasses and summer annual forbs that remain green into the summer months to reduce fire hazards.

Criteria for Selecting Treatments

In addition to being effective against the target plants, treatments should also meet the following criteria to ensure that designated treatments also meet the WSDOT Roadside Vegetation Management Program *overall objectives.* A preferred treatment should be:

- Most cost effective in the short and long term
- Most likely to be permanent
- Easiest to carry out effectively
- Least hazardous to human health
- Least likely to affect ground or surface water quality
- Least disruptive of natural controls
- Least toxic to nontarget organisms
- Least hazardous to human health

Example: A decision is made to apply an herbicide to Scotch broom, Cytisus scoparius, *and two registered products are under consideration: glyphosate* (Roundup®) *and 2,4-D (Weedone®). Applying the "least hazardous" criteria would lead to a choice of glyphosate which is less acutely toxic to humans than 2,4-D. The oral lethal dose (LD_{50})for glyphosate is 4300 mg/kg of herbicide compared to 375 mg/kg for 2,4-D. A product with the highest number is the less-toxic.*

Least Likely to Affect Ground or Surface Water Quality

Example: Broadcast herbicide applications to control yellow starthistle, Centaurea solstitialis, *may lead to contamination of nearby surface water through drift or runoff. Mowing yellow starthistle to a height of 2 to 3 inches when about 5 percent of the individuals present are visibly flowering will prevent seed set and effectively control this noxious weed without risking contamination of nearby surface waters.*

Least Disruptive of Natural Vegetation Controls

Example: A decision is made to mow an area containing a stand of Canada thistle, Cirsium arvense, *which is being fed upon by a predatory weevil,* Ceutorhynchus litura. *The weevil is capable of killing 90 percent of thistles in areas with long, cool springs (Powell et al. 1994). The manager delays the mowing operation until late summer when adult weevils have finished feeding and moved into the leaf litter to overwinter. They will emerge in spring to attack young rosette-stage thistles.*

Least-Toxic to Nontarget Organisms

Example: Spot sprays of herbicides are preferred to broadcast sprays because they are less likely to produce residues that can drift, leach, or runoff onto nontarget sites or organisms. In some cases where even more care is needed in selectivity, a wick application may be desirable.

Most Likely to Produce Permanent Reduction in the Pest Population

Defining treatments that meet this criteria is at the heart of a successful IVM program because these treatments work without extra human effort or continual inputs of other resources. In general, such treatments reduce the life support systems needed by problem plants, or place permanent physical barriers between soil and undesirable vegetation. In areas chronically infested with pest vegetation, maintenance practices that follow-up mechanical or chemical removal with treatments involving plantings of dense stands of beneficial vegetation will permanently discourage problem plants by denying them the disturbed, bare soil conditions they need for germination and growth.

Example: In the dry areas of the Columbia Basin, large stands of yellow starthistle, Centaurea solstitialis, *can be mowed in spring when at the bud stage to prevent both seed production and regrowth. The mowed area can be disked and fallowed till fall when a mix of native grasses such as Idaho fescue and bottlebrush squirreltail plus legumes such as vetch or clover can be seeded to form a dense, competitive cover that resists reinvasion by thistle and other weeds.*

Example: In western Washington, dense stands of Scotch broom four years or older can be cut at the root crown just prior to flowering, and the severed tops chipped and spread as a mulch 4 to 6-inches deep. This treatment will prevent most stump-sprouting and seed germination by broom. In the fall, plantings of salal, huckleberry, or native grasses and forbs can be established in the area formerly occupied by the broom.

Example: By constructing an extended asphalt shoulder in a 6:1 taper 2 inches to 3 inches beyond the normal edge of pavement, the need for Zone 1 can be eliminated.

Easiest to Carry Out Effectively

Example: Herbicides can only be safely and effectively applied when weather conditions are suitable. When temperatures are hot, the protective clothing and other gear worn by pesticide applicators often causes discomfort and reduces effectiveness of their work. The heat also causes herbicides to volatilize, creating the potential for drift onto nontarget organisms. When weather is wet or windy, herbicides cannot be applied due to concerns about drift or runoff. Thus, while the application of herbicides may appear comparatively simple, in practice, it may not be the easiest tactic to carry out safely or effectively.

Most Cost Effective in the Short- and Long-Term

This is often far more difficult to calculate than it might seem initially. To obtain a complete picture of the economics of a treatment, tactic, or strategy, it is important to include all the costs that might be involved, not simply the costs of labor, materials, and equipment. True costs also include a contingency factor and built-in infrastructure expenses associated with a particular treatment method.

Example: When calculating the complete costs of an herbicide program, "indirect" costs for pesticide certification and training of employees, secure pesticide storage facilities, pesticide use reports, disposal of unused pesticides, cleanup of spills, liability from drift, runoff, etc., and public relations must be included along with "direct" costs of labor, materials, and equipment. When total cost factors are *considered, applying a herbicide may not be the most cost effective tactic in the long run, although in the short term it may appear to be the least expensive among the options considered.*

When assessing cost effectiveness, among the factors to consider are whether the costs of a particular tactic or treatment are one time, or are likely to recur a number of times during the season, or from year to year.

Example: Herbicides can be used annually to kill or knock back noxious weeds such as thistles, tansy ragwort, knapweed, toadflax, blackberry, salmonberry, etc. that invade bare soil in recently graded areas. But unless follow-up tactics are used to change the habitat conditions supporting the weeds, new seedlings or resprouts will emerge each year on the bare soil, requiring repeated sprays year after year.

A more permanent and cost-effective solution is to incorporate weed prevention strategies into grading specifications and practices. Prior to grading, a replanting treatment plan for the graded site should be prepared and sources of seed or other plant materials identified. When grading begins, native top soil can be stockpiled at the site and covered with a tarp to prevent colonization by weeds. As soon as possible after grading and construction is completed, the top soil can be respread and seeded or planted with native or adapted plants suited to the ecological constraints and functional objectives of the site. Once established, the beneficial plants will be self-sustaining and competitive against weeds.

Applying Treatments

In addition to considering department objectives and using the criteria list to optimize treatment choice, details about the *timing, rate,* and *placement* of treatments must be determined. *Treatment timing i*s the point in the target plant life cycle, the general season, or the maintenance schedule when the treatment should be applied. The *treatment rate* is a critical quantity that defines the treatment action. This may be amount of herbicide used at a given dilution over a given area, the density of seeding or planting of transplants of beneficial vegetation, the height a plant should be cut, the number of biological control organisms to release over a given area, the depth of mulch to apply, the amount of fertilizer or water to apply to a given area, and so on. The *treatment placement* is the *exact* area where the treatment action is applied. Inappropriate treatment timing, rate, or placement may result in unintended side effects, excessive costs, hazards to personnel and the public, and secondary or recurring maintenance problems.

Timing Treatments

Chapter 1 contains examples of how timing of treatments is important in the life cycle of desirable plants and wildlife, problem plant species, and the operational and socio/political system (maintenance activities, laws and regulations, adjacent landowners, etc.) that surround them. Monitoring provides the critical information from these plant/human systems needed for effective timing of treatments.

Example: Protection and enhancement of wildlife habitat along roadsides is one of the department's IVM goals, and a high priority concern of tribal councils, sporting organizations, native plant societies, natural resource agencies, etc. Both mechanical and chemical treatments for vegetation control can adversely impact *wildlife and their habitat if improperly timed. By inventorying wildlife species occupying the roadside rights of way and noting locations where feeding, nesting, migration, etc., occur, maintenance activities can be timed to reduce negative impacts on wildlife habitat.*

For instance, in sites where monitoring has revealed the presence of burrowing owls, pheasants, or other ground nesting birds, mowing, controlled burns, spraying, or revegetation treatments should be timed to take place after fledglings have left the nests. When revegetation treatments for such areas is planned, shrubs and trees should be incorporated into the planting treatment plan to provide more permanent cover and reduce the volume of grasses that require mowing and other disruptive management practices.

Placement of Treatments: Spot Treatment

Treatments should always be applied only where they are needed, not over a broad, generalized area which contains patches of problem vegetation.

Spot treatment refers to applying chemical, manual, mechanical, or other treatment tactics just on those plants or sites where *action levels* have been reached. In the case of herbicides, spot treatment (or spot spray) can also refer to methods that minimize amounts of material used. The spot treatment approach contrasts with broadcast application of herbicides, mowing, etc. over large areas. In IVM programs, the spot treatment approach is preferred because it helps reduce soil disturbance that invites reinvasion by weeds, is less likely to result in negative impacts on watersheds, wetlands, wildlife habitat, beneficial plants and other natural resources, and is less costly because less time and fewer materials are required.

Example: Common practice when using an herbicide to control brush like Scotch broom, blackberries, alders, etc., is to apply a broadcast spray over the foliage. A spot treatment approach would first sever and remove the above-ground portions of the plant, leaving a short stump which would be immediately treated with a small amount of herbicide via injection, wick applicator or other careful spot spray. The spot treatment approach not only substantially reduces total herbicide active ingredient, but avoids drift and limits applicator exposure. This approach also avoids fire hazards associated with broadcast foliage sprays that leave dead plants standing.

Determining Treatment Rates

For herbicides, appropriate treatment rates are generally indicated by the label. WSDOT maintenance staff experience may provide useful adjustments for rates of some herbicides used in applications unique to WSDOT maintenance practice. The lowest effective rate should always be used to minimize cost, hazard to the applicator, and environmental impact.

For other tactics, treatment rates may be more difficult to determine. This is especially true of seeding and planting densities for native plants and release rates for biocontrol agents. The department horticulturist and other technical experts can provide guidance until WSDOT develops a more complete knowledge base of treatment rates. Eventually, such information will be readily accessible from a WSDOT treatment reference database.

Chapter 6 Evaluating the Effectiveness of the IVM Program

One of the most important components of an Integrated Vegetation Management (IVM) program is evaluating whether or not it is working, and fine-tuning it when necessary. In some cases area programs may practice routine mowing and spraying without questioning the efficacy of what they are doing. An IVM-oriented program would view the need to regularly apply chemical treatments as an indication that the program was not working efficiently, and seek other solutions in order to reduce herbicide use and maximize natural succession for the establishment of beneficial vegetation.

For the purposes of overall evaluation, it is helpful to consider all simultaneously occurring interacting systems or processes of the IVM program:

- Monitoring
- Record-keeping of field data
- Decision making regarding treatment activities
- Implementation of treatments
- Evaluation of treatments
- Collection and cataloging of reference materials on roadside vegetation maintenance
- Education and training of roadside maintenance personnel on IVM
- Communication to roadside maintenance crews and others regarding IVM particulars and progress
- Budgetary planning
- Evaluation of overall IVM program

Each of these components should have, as part of the development of the initial IVM program plan, some expressed objectives or criteria by which the component is judged successful or not. But, in addition, it is important to determine:

- Were all the necessary components to the program actually developed?
- Were they integrated successfully?
- Were the right people involved in the integration of the components into a whole program?

At the end of an annual management cycle, use the monitoring data to answer the questions listed in the following section, and make any necessary adjustments in choice of tactics and treatments and planning of monitoring activities for the next year. After two or three years of fine-tuning, including establishment of beneficial vegetation, redesigning of roadside structures and ditch profiles, or changing typical maintenance activities to encourage beneficial vegetation, managers can generally expect vegetation management problems to have lessened considerably, and in some cases disappeared. When this point is reached, periodic monitoring rather than active management may be all that is required.

Questions to Ask at the End of the Season

- Was the problem vegetation adequately controlled or beneficial plants adequately encouraged in terms of injury levels?
- Was the problem vegetation controlled in a timely manner?
- Was beneficial vegetation established or cultivated when needed?
- Were planned procedures used? If not, what was different?
- What were the costs of maintenance efforts and how did they compare with costs associated with maintenance prior to IVM implementation (or the prior year)?
- What problems occurred and how severe were they?
- Was beneficial vegetation affected by maintenance efforts? How?
- If beneficial vegetation was killed by weed suppression treatments, will this cause future problems on the site?
- Were there any other side effects from the maintenance efforts?
- Were the side effects added to the cost of maintenance efforts? If ineffective, should the maintenance efforts be repeated? If ineffective, should another kind of treatment or tactic be evaluated?
- Can the site be changed to eliminate or reduce the problem for the same costs of maintenance efforts?
- Were there unanticipated consequences (good or bad) of old or new strategies, tactics, or treatments used?

Cost Effectiveness

Cost effectiveness is central to a decision to continue an IVM program. In Chapter 1, one example of the potential economic benefits of IVM programs was described in the Iowa IRVM Program example (**Box 1-A**). It is important to keep in mind that the transition period to IVM will probably involve *investing* in roadside management to achieve stable vegetation that will reduce maintenance costs in future years. Natural succession takes years to unfold. You may find that total annual costs drop during the first year of IVM. It is also possible that they may increase somewhat for the first two or three years of the program, then decline rapidly and stabilize well below average historical costs of maintaining roadsides from that point on.

8:P:DP/IVM

Introduction

Education is a critical and cost-effective vegetation management strategy. It is in the long-term interest of the Washington State Department of Transportation (WSDOT) to be proactive in educating WSDOT personnel, key officials in other agencies and institutions who interact with WSDOT, and the general public on the merits of Integrated Vegetation Management (IVM). Tolerance for certain plant and animal species and a general understanding of the benefits of taking an ecosystem approach to vegetation management can be increased by education.

Who Needs to Receive Information?

All parties to vegetation management decision making and implementation need information about IVM. This includes, at minimum:

- Maintenance supervisors, lead technicians, and pesticide applicators
- Engineering and design staff
- Regulatory agencies
- Adjacent landowners
- Media and the general public

Each of these groups need information on the general IVM philosophy that underlies the vegetation management program as well as updates on accomplishments.

Maintenance personnel need to understand the importance of monitoring as well as the role that their horticultural and maintenance practices play in regulating vegetation populations. This understanding is critical to building staff support for IVM. It is also critical that maintenance staff receive education and training in proper horticultural practices, since IVM programs require skills in protecting and expanding plantings of beneficial vegetation. Use of existing in-house media such as maintenance technical bulletins and a Maintenance Newsletter can be directed toward this effort.

Engineering and Roadside Design staff need to understand the biological and ecological functions of vegetation so engineering design and maintenance standards can better accommodate the inevitable behavior of vegetation along roadside rights of way. Close coordination between maintenance and design staff such as that which took place with the Zone 1 Task Force Study can produce important modifications in vegetation management programs such as the recent decision to narrow the “bare earth” requirements in Zone 1.

Regulators from the Departments of Ecology, Agriculture, Natural Resources, and the U.S. Environmental Protection Agency need to know that IVM programs promote early detection of weed problems, and expand nonchemical vegetation control options. This in turn helps reduce nonpoint source pollution problems with herbicides, destruction of wildlife habitat, and other problems of concern to these agencies. A good record-keeping system flowing from the monitoring program can substantiate the effectiveness of IVM to regulatory personnel.

Adjacent landowners increasingly express concerns and/or file complaints about herbicide drift or water contamination. By providing them with information on the IVM program, WSDOT maintenance personnel can demonstrate a good faith effort to minimize use and off-site movement of toxic materials. This can help diffuse conflict with neighboring property owners. Involving adjacent landowners in the IVM program can also help resolve conflicts in eastern Washington where agricultural operations encroach on WSDOT rights of way resulting in erosion, air quality problems, and loss of native vegetation.

Media and the general public need to know how citizens can help reduce soil disturbance and the spread of weeds on roadsides. They also need to know that WSDOT has a "good neighbor" policy and is making a good faith effort to reduce environmental and wildlife impacts associated with its vegetation management activities. **Box 7-A** lists potential public education activities.

IVM Educational Goal

The goal of IVM educational activities is to encourage people to look at the whole picture, that is, to include biological, ecological, psychological, sociological, and long-term economic factors when developing a vegetation management program. This usually involves:

- Modifying aesthetic attitudes regarding the appearance of roadside vegetation
- Increasing tolerances for presence of some weeds
- Increasing understanding of basic biological and ecological processes underlying vegetation management
- Focusing on alternative treatments instead of relying on herbicides as the first choice method

Modifying Aesthetic Attitudes Regarding the Appearance of Roadside Vegetation

Example: A large proportion of the vegetation grown in Zones 2 and 3 along roadsides is comprised of grasses. Because of widely held cultural aesthetics, roadside mowing practices are often geared to develop a "lawn-like" appearance — particularly, but not exclusively, in the vicinity of urban areas. This is not only expensive to achieve, but it can result in thinning of grasses by reducing photosynthesis, seed production, etc., which in turn allows weeds to invade.

An alternate approach is to cultivate a "meadow" aesthetic for roadsides where wildflowers are encouraged and grasses are mowed only when necessary (e.g., where flammability is of concern), mowing heights are raised to 12 inches or higher in order to minimize habitat for weeds, and mowing is timed to minimize impacts on wildlife. This approach will reduce mowing frequency, netting cost savings to the department. However, it will take a public relations effort both within and outside the department to gain support for this approach in the vicinity of urban areas.

Box 7-A. Building IVM Awareness

Building public awareness and support for the department's IVM program is essential. The following educational activities have been effective in the State of Iowa where roadside IVM programs have a long history.

- **Develop a mailing list** of key individuals, agencies, and organizations, and media contacts**.**
- **Prepare a well-polished general program** that can be provided on short notice. Make use of videos, slides, transparencies and other visual aids. A minimum amount of tailoring will be necessary for most audiences. Let it be known the department is happy to provide this service.
- **Submit articles and news releases** to publications about the IVM program. Newspapers and television stations favor press releases based on an upcoming event or something out of the ordinary. Use seasonal roadside activities and environmental aspects of the program. Share discoveries you make on your roadsides.
- **Develop programs to educate landowners** on the benefits and cooperative opportunities of the IVM program. Work with landowners to reduce siltation and sedimentation in drainage ditches.
- **Prepare an education package** for use in classrooms both indoors and outdoors. Design activities that require or provide for student participation. Include materials that can be passed around the room, handled, looked at up close, or taken home to parents.
- **Publish information** pamphlets on the IVM program for distribution to conservation organizations, garden clubs, libraries, schools, and other community outlets.
- **Install a demonstration planting** in a highly visible area. Involve summer interns in innovative demonstrations.
- **Stay in contact with relevant agencies** such as the Natural Resources Conservation Service, Cooperative Extension, County Agricultural Commissioners, etc. Go to their meetings and explain IVM objectives.
- **Work with environmental organizations and native plant societies.** Involve them in focus sessions and field demonstrations.
- **Keep WSDOT engineering and maintenance managers aware** of program progress.
- **Emphasize to WSDOT maintenance crews that each one of them is a spokesperson for IVM** and encourage them to watch for opportunities to represent the program positively and to elaborate on its contributions to the state.
- **Establish an advisory committee i**n each maintenance district to keep maintenance supervisors informed about public opinion, help shape the direction of the IVM program, and act as good will ambassadors for the program.

Increasing Tolerance for Presence of Some Weeds

Example: Education can help people realize that the presence of some "noxious weeds" on the roadsides can be a benefit rather than detriment to overall control of noxious weed species. By tolerating some clumps of tansy ragwort, Senecio jacobaea*, knapweed,* Centaurea *spp., etc., in key locations, the plants can serve as insectaries for rearing insects and mites (biological control organisms) that attack these weeds. This approach will not only help reduce existing infestations, but will also insure that some natural enemies are always present to respond to the constant reintroduction of noxious weeds from automobile tires, bird droppings, etc.*

Increasing the Understanding of an Ecosystem Approach to Vegetation Management Decisions

Vegetation management actions usually flow from value judgments regarding other species with which humans come in contact. Teaching concepts such as "food webs," behaviors of predator/prey populations, vegetation succession, etc. can help people recognize the value of species otherwise thought of as pests or as unuseful. This can lead to increased tolerance of "weed" species, and horticultural designs and activities that are supportive of natural enemies and competitors of undesirable plants.

Focusing on Alternative Treatments Instead of Relying on Herbicides as the First Choice

Problems with herbicides include: significant weed resistance to registered materials, contamination of surface and ground water, increased regulation and litigation, withdrawal of products from the market, increasing costs, employee concerns about herbicide exposure, and complaints from adjacent landowners and the general public about nontarget impacts. These are all reasons to reduce reliance on chemical controls.

9:P:DP/IVM

Forms

Record keeping for an Integrated Vegetation Management (IVM) program should be convenient and easy to use for the maintenance employee doing the work. It is perfectly acceptable for individual crews or maintenance areas to develop their own forms and systems. Typical information to be considered is discussed in Chapters 2 through 6.

The Field Operations Support Roadside Maintenance Office in the Olympia Service Center is also developing a IVM database with a series of forms for data entry. This system is currently under development, contact Ray Willard (360) 705-7865 for the latest information.

The following Forms 1-1 through 1-4 are the basis for data entry to the IVM Database.

10:P:DP/IVM

SITE DESCRIPTION FORM

Site Name: | County: | Site ID: 0

Region: | Maintenance Area:

SR: | MP: | to MP:

Side of Road: ☐ Left ☐ Right ☐ Median

Site Description

Roadside Management Zones
☐ Zone 1 ☐ Zone 2 ☐ Zone 3

Site Acreage:

General Site Description:

Soil Type/Description:

Depth to Water Table
☐ Greater than 10 feet ☐ Less than 10 feet

Typical Vegetation Type:

Form 1-1

SITE ANALYSIS/MONITORING FORM

Site Name: ______ County: ______ Site ID: 0

Region: ______ Maintenance Area: ______

SR: ______ MP: ______ to MP: ______

Side of Road: ☐ Left ☐ Right ☐ Median

Date: ______ Site Analysis by: ______

Site Management History:

Undesireable Vegetation Inventory

Noxious Weeds	% Coverage	Action Threshold
Noxious Weed 1:		
Noxious Weed 2:		
Noxious Weed 3:		
Noxious Weed 4:		
Noxious Weed 5:		

Noxious Weed General Distribution

Nuisance Vegetation	% Coverage	Action Threshold
Nuisance Vegetation 1:		
Nuisance Vegetation 2:		
Nuisance Vegetation 3:		

Nuisance Vegetation General Distribution

Functional Objective Impacts

Functional Objectives

Which roadside functional objectives are impacted by the presence of undesireable vegetation? Check all that apply.

- ☐ Noxious Weed
- ☐ Hazard Vegetation
- ☐ Prevent Erosion
- ☐ Positive Drainage
- ☐ Site Distance
- ☐ Sign Visibility
- ☐ Hardware Maintenance
- ☐ Utility Accomodation
- ☐ Wildlife Habitiat
- ☐ Aesthetics
- ☐ Neighbor Relations
- ☐ Fire Prevention
- ☐ Ice Prevention

Comments on functional objectve impacts

Form 1-2

TREATMENT PLAN FORM

Site Name: ______ County: ______ Site ID: 0

Region: ______ Maintenance Area: ______

SR: ______ MP: ______ to MP: ______

Side of Road: ☐ Left ☐ Right ☐ Median

Date: ______ Treatment Plan by: ______

Strategies
☐ Prevention ☐ Early Treatment ☐ Maintenance ☐ Correction ☐ No Action

Objectives
☐ Eradication ☐ Control ☐ Contain ☐ Reduce ☐ Monitor

Treatment Methods

☐ Manual	☐ Lopping ☐ Pulling ☐ Digging ☐ Scalping	Planned Date of Initial Treatment:	
		Planned Date of Follow-up Treatment:	
☐ Mechanical	☐ Mowing ☐ Brushing ☐ Plowing	Planned Date of Initial Treatment:	
		Planned Date of Follow-up Treatment:	
☐ Bio-Control	☐ Pathogens ☐ Parasites ☐ Insects	Planned Date of Initial Treatment:	
		Planned Date of Follow-up Treatment:	
☐ Cultural	☐ Burning ☐ Grazing ☐ Seeding ☐ Fertilizing	Planned Date of Initial Treatment:	
		Planned Date of Follow-up Treatment:	
☐ Chemical	☐ Herbicides	Planned Date of Initial Treatment:	
		Planned Date of Follow-up Treatment:	

Additional Instructions and Comments

Form 1-3

TREATMENT RECORD FORM

Site Name: ______ County: ______ Site ID: 0

Region: ______ Maintenance Area: ______

SR: ______ MP: ______ to MP: ______

Side of Road: ☐ Left ☐ Right ☐ Median

Date: ______ Treatment Record by: ______

Targeted Weeds

Target Weed 1: ______

Target Weed 2: ______

Target Weed 3: ______

Target Weed 3: ______

Target Weed 5: ______

Target Nuisance Vegetation

Target Vegetation 1: ______

Target Vegetation 2: ______

Target Vegetation 3: ______

Treatment Record

☐ Manual Treatment

Description of Manual Treatment:

☐ Mechanical Treatment

Description of Mechanical Treatment:

☐ Cultural Treatment

Description of Cultural Treatment

☐ BioControl Treatment

Description of BioControl Treatment

Agent Released: ______ Quantity Released: ______

☐ Chemical Treatment

Chemicals Used:

Application Method: ______ Pesticide Application Record Num.: ______

Cost Report

Labor Cost: ______ + Equipment Cost: ______ + Material Cost: ______ = Total Cost: ______

Additional Notes:

Form 1-4

How to Create and Manage a Successful Test Area

A successful test area will allow an investigator to determine:

- That treatments are working or do not work
- The reason why treatments work or do not work
- That one treatment is superior to another
- The extent to which one treatment is better than another

To provide this type of information, a test area must have the following characteristics:

- It is **large** enough for several treatment plots to exist side by side without treatments in one plot affecting plants in another
- The vegetation is **uniform** enough for each part of the area to be representative of the whole
- The area is **accessible** to both monitoring personnel and the staff and equipment that will apply the treatments
- The site **will not be disturbed** by construction or other activities within the next two years at least

Once such an area has been identified, the area must be prepared for the study. Using stakes, mark off subdivisions of the area. At minimum, you will need:

- A plot which receives no treatments; this plot, called the *control plot*, provides the standard of comparison to show the relative effectiveness of the treatments
- A plot which receives a treatment typical of current methods
- At least one plot receiving the new, experimental treatment. Ideally, several plots with variations on the experimental treatment, such as different cutting heights for a mowing treatment, should be included

Next, clearly label the study site and each of the plots. At minimum, the area itself should be identified as a study area on a sign visible from a distance. Warnings not to disturb the area should be visibly posted from all approaches to the area. Informing staff through memos or verbally is important and effective, but on-site posting provides the most security. Clear labeling greatly speeds monitoring efforts and prevents treatment errors which could ruin the experiment.

Study areas should be monitored frequently. Study site managers must be aware of loss or obstruction of signs, inadvertent treatment applications, accidents, or acts of nature which may affect the study area as well as changes in the vegetation which are ordinary responses to growth and management. Managers must also be prepared to apply treatments and evaluate results at the appropriate time. Choosing a site which is near the manager's principle office or along a frequently traveled road will help insure that monitoring occurs when it is needed. Forms should include a clear indication of which plot (treatment) they refer to. All of the plots should be monitored at the same time, and control plots should be monitored along with the rest. Monitoring forms should contain the types of information already detailed in Chapter 2.

Keep the monitoring records for the study site separate from records for other areas. When treatment evaluation monitoring is complete, use the monitoring records and any other sources of information and expertise available to generate a report detailing recommendations about the treatments tested. This report becomes part of the permanent knowledge-base of the Washington State Department of Transportation.

11:P:DP/IVM

Ways of Qualifying And Quantifying Vegetation Characteristics

Plants and plant characteristics can be measured (height, width, the area the plants cover, weight), counted (number of individuals, number of flowers or seed heads), or described (tall, short, vigorous, weak, flowering, seeding, spreading, etc.). Characteristics such as germination success for beneficial vegetation, growth vigor of beneficials, how well beneficial vegetation is suppressing weedy species, and how much area is covered by noxious weeds, can be rated on a 1-5 or 1-10 scale. Descriptions should always include a note about what the observer means by the description. For example, “tall” grass may be anything over 20 inches and “vigorous” grass may mean dense and dark green plants. Wherever possible, rating scales agreed upon by everyone involved in monitoring should be used.

The way observations are quantified or qualified will depend on the characteristics to be measured and the nature of the vegetation. Plants that stand out as individuals can simply be counted, but other vegetation may require different measures. For example, it is nearly impossible to count individual grasses, herbaceous plants, or broadleaf weeds because they are so numerous. Also, most grass species grow by spreading, so it is difficult to identify an “individual” grass. For these types of vegetation, it is best to use cover as a measure of plant activity. Cover is estimated as a percentage of an area occupied by the plants. How large an area is not important, per se, as long as the size of the area is known and can be recorded. Estimation is done using a technique called visua*l packing*, which is described in Appendix 5. Cover provides an accurate assessment of plant activity because plants influence each other and the environment through their root and crown systems. The area a plant covers is thus the area it influences. Many smaller plants covering the same area as fewer, larger plants would appear quite different if counted but measure the same as amount covered, which thus provides more accurate and reliable information.

12:P:DP/IVM

Techniques for Visual Monitoring

It is important to decide how information will be gathered along roadside segments. Roadside maintenance management plans may be developed by dividing roadsides into segments by mile-marker or maintenance control sections, roughly setting boundaries where vegetation or topography changes significantly. These segments probably have management histories that can be accessed by current managers. Within these segments, there are a number of ways to monitor the area effectively.

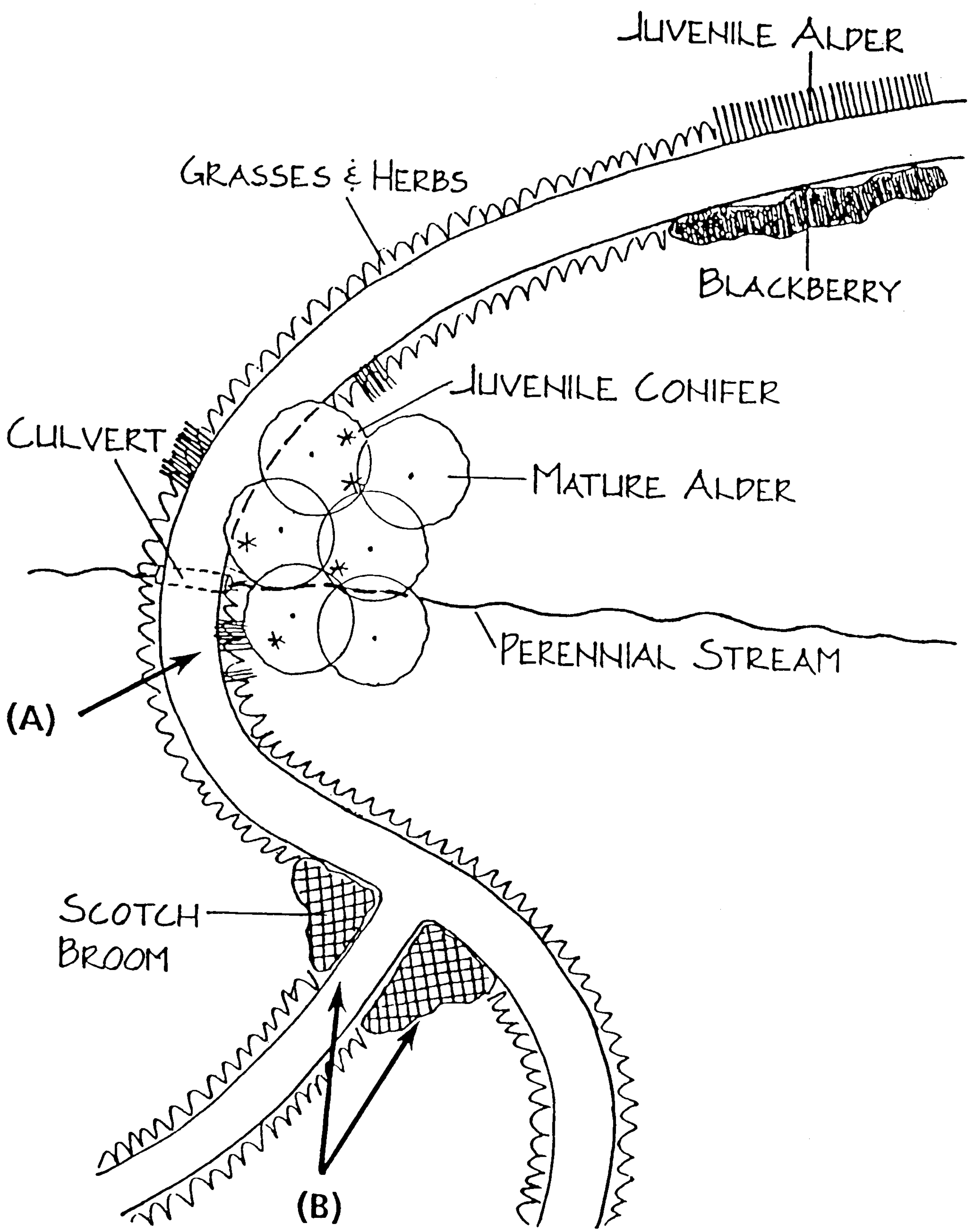
The first method is to simply drive by and look at the vegetation while keeping functional objectives in mind. Make notes of areas that appear to deserve special attention because of the presence of either desirable or problem vegetation. General impressions of roadside vegetation, in terms of its composition and the growth stages of plants, can be gathered this way. Specific information on how vegetation is changing is not retained, however. **Illustration A4-1** shows a sketch of a section of road where mature vegetation is causing sight distance problems, and where juvenile plants are likely to become problems in the future. This type of sketch can be filed with a monitoring form.

Another method is to sample selected areas using more rigorous monitoring techniques. An area may be chosen because it hosted noxious weed populations in previous years, or because there are several functional objectives related to it, or because a new management technique was tried and results need to be evaluated, etc. Selection of the monitoring area is a judgment made by the person responsible for vegetation management. **Illustration A4-2** shows test plots of two types of mulches and an untreated control plot located at one roadside area. Data from the test plots is gathered at several times in the season and noted on the monitoring form. If this technique is used, it will be necessary to involve the department horticulturist.

A third method is to randomize monitoring areas within a relatively uniform stretch of roadside, and sample repeatedly. This method provides data that can be used to perform objective, statistical analysis, but is the most time consuming.

Example: A representative inventory of roadside vegetation can be cost-effectively accomplished by selecting a number of same-sized plots per shoulder mile and estimating percent cover of target plant species in each plot. This might be described in the following manner, "20 plots were established for each shoulder mile. Plots were 264 feet long and as wide as the management zone at that location (minimum 10 feet). In addition, each plot was divided into maintenance Zones 2 and 3" ***Illustration A4-3*** *shows a sample monitoring form with checkoff boxes.*

It is also useful to produce a *random sample* data set. To do this, arbitrarily select a mile marker as a starting point and record the mile mark. At random intervals along the road, stop to look at the vegetation using whatever methods you have chosen. Record the distance between one monitoring point and the next as well as the conditions observed. Repeat this process five to ten times along a given roadside management segment. Work will pass more quickly if a passenger records the data.



Line of Sight Problems- (A) & (B)

Illustration A4-1 (Option)

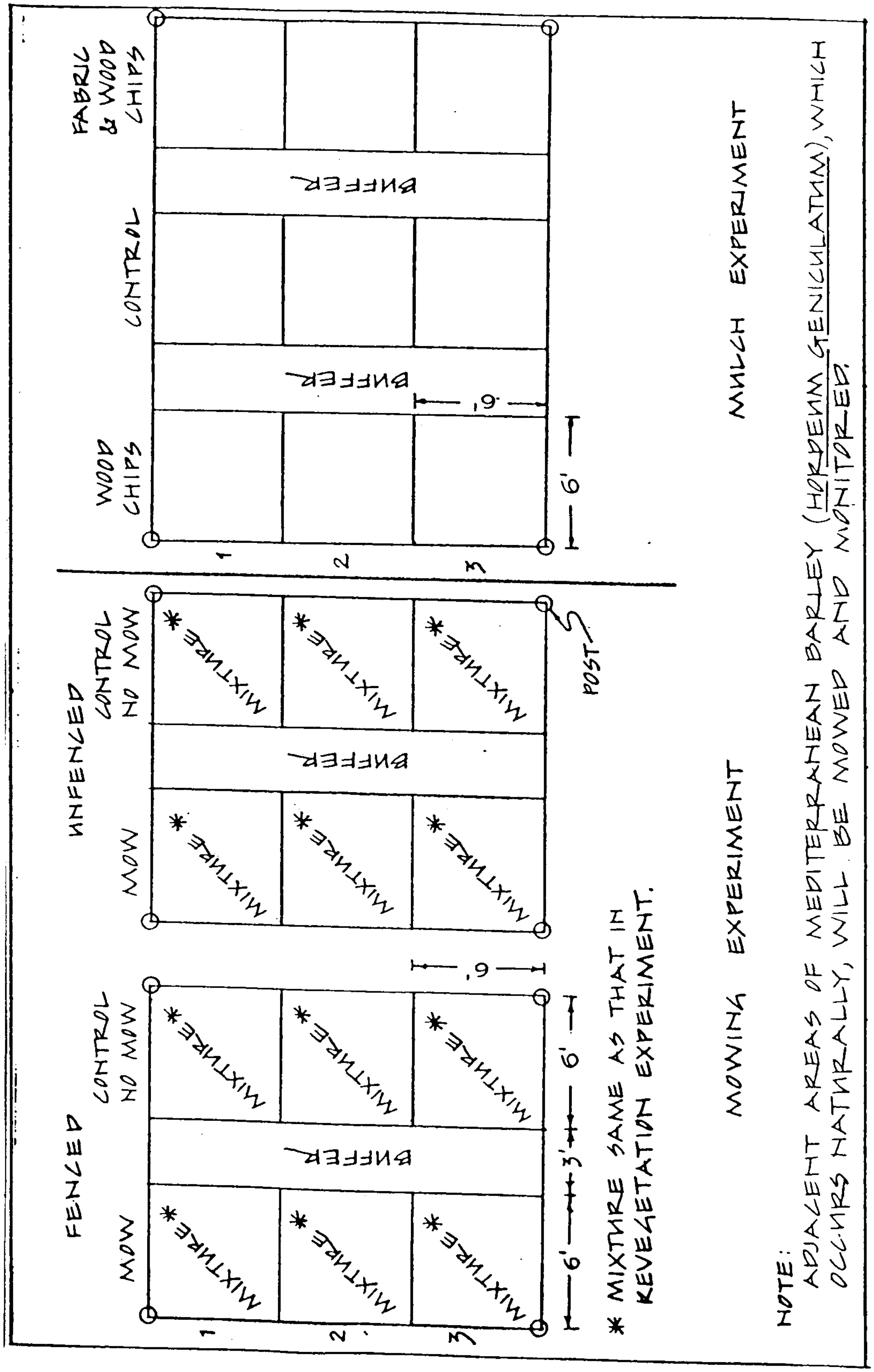


Illustration A4-2

Target Species
Roadside Vegetation Inventory

Road Number: _____ Milepost: mp# _____ to mp# _____ Milepost Section: _____

Right Side of Road

Shoulder and Ditch

Plant Species	Sdling	Jvl	Mat	Dist
Ainus Rubra				
Acer macrophyllum				
Ceanothus spp				
Cytisus scoparrus				
Rubus discolor				
Rubus spectabilis				
senecio jacobea				
Conifer spp				

Cut or Fill Bank

Plant Species	Sdling	Jvl	Mat	Dist
Ainus Rubra				
Acer macrophyllum				
Ceanothus spp				
Cytisus scoparrus				
Rubus discolor				
Rubus spectabilis				
senecio jacobea				
Conifer spp				

Illustration A4-3

Ideally, some combination of methods should be used. In all cases, activities should be organized to achieve a *representative* sample in the least amount of time. When planning a route to follow, make sure to include time to visit areas that have been the site of more intensive maintenance in the past. Along the route, try to sample roadside vegetation at some interval (e.g., at every other mile-marker; or every ¼-mile, etc.). Monitoring repeatedly along a linear route is called “doing a transect.” For roadside managers, most transects will be worked from a vehicle, and can thus be called *“truck transects.”*

It is important to be able to return to the exact same area when conducting ongoing, repeated monitoring activities. Locating plots adjacent to permanent structures will facilitate this. Culverts, guard rails, and roadside signs may serve as markers, with plot locations noted by distance and direction from the marker (“10 yards south of the Exit 29 sign” etc.). Mile markers may be particularly useful markers for plot locations. Hopefully, designated *focus areas* will contain one or more of these types of markers for use in locating monitoring plots.

Remember, *always record where and how monitoring samples were collected for future reference.*

13:P:DP/IVM

There are a number of monitoring tools that aid in collecting and recording accurate information about plant communities. Different tools are designed to facilitate collection of different kinds of data, depending on what is appropriate for the type of vegetation being monitored.

Sampling Frames for Estimating Cover

Researchers use a variety of tools to estimate cover. All of them involve framing a known area of vegetation, either by sighting through a framing device or actually laying a frame down around vegetation, then using ***visual packing*** to estimate the percentage of the framed area occupied by each species. **Illustration A5-1** explains how to do visual packing. Researchers commonly use a devise called a Daubenmire Frame (Daubenmire 1959) for sampling in grasslands. In all cases, it is important to be looking *straight down* on the vegetation to get an accurate estimate of cover.

Most of these devises are time consuming to use properly. But any *repeatable* method of framing an area of vegetation will work. The following examples are both relatively quick and sufficiently accurate for the Washington State Department of Transportation (WSDOT) needs.

Vehicle Window Frame. If roadsides are typically inspected from a pickup truck, the passenger side window can be used to visually frame an area. Simply look through the window while sitting in the driver’s seat and visually pack species or vegetation types, then record the results before driving on. So long as the same truck (with the same size window) is used to sample vegetation that is about the same distance from the truck during each monitoring visit, and the shoulder is somewhat sloped so that a view from the window looks down into the vegetation, results should be accurate.

Daubenmire-type Frame. You can also build a frame from wood or PVC pipe and carry it in the truck with you. The frame can be placed on the ground and visual packing used to estimate cover.

Bumper Method. An area can also be defined by parking the truck, walking into the roadside vegetation, then looking back to use the truck’s front and rear bumpers to define one side of a square.

Permanent Plots. Permanent plots that are visited repeatedly over several years can be marked by pounding four colored stakes to define a square or rectangle, then inspected from the truck. This method is especially valuable for monitoring plantings of beneficials or natural patches of vegetation that are being encouraged to spread.

Mile Marker Example in Box?

Regardless of the sampling method used, it is important to be looking as nearly straight down on the vegetation as possible to obtain an accurate estimate of cover. Sloped roadsides can be sampled this way with truck window or truck bumpers for defining the area. Flat roadsides may require leaving the truck and laying a frame.

Tools for Estimating Vegetation Height

Vegetation height bears upon many functional objectives typical of roadside management, including maintaining visibility on curves, maintaining sign visibility, and preventing shading of the road in areas prone to ice problems. Brightly painted stakes, marked to define a particular height, can be installed at intervals along roadsides early in theIntegrated Vegetation Management (IVM) program to facilitate future monitoring. A simple glance from a truck window is sufficient to see if vegetation is above or below the mark. The mark can be set to indicate either an *injury level* or an *action level* (discussed in Chapter 3 and 4). Stakes can also be used to indicate optimum mowing height.

Tools for Counting

Keeping count mentally can be difficult to maintain over the course of an afternoon of monitoring. Using a simple tallying counter or “clicker” to click-off individual plants as they are counted will help keep plant tallies accurate.

Forms

Forms are monitoring tools because they help organize monitoring data that is collected. Each blank on the form reminds the manager of what needs to be recorded and how to record it. A good form will also serve as a reminder of the relationship between the management goals (functional objectives) and the vegetation being monitored (see **Appendix 1** for a sample monitoring form).

Plant Identification Keys

It is important to be able to accurately identify both problem and beneficial vegetation. In conjunction with the department horticulturist, a key to species typical for a specific maintenance area should be developed early in the IVM program. The key should include photographs or high quality drawings of each species at different points of its life cycle and any maintenance and treatment related information available. The key will help staff learn to easily identify the species over time, making future monitoring less time consuming.

Camera

Cameras are invaluable tools for documenting changes in roadside vegetation over time. If possible, monitoring activities should always include taking photographs of monitored areas.

Reminders

During the early stages of adopting IVM monitoring practices it may be difficult to remember all important aspects of monitoring. Carry a copy of this manual or laminated photocopies of key portions, such as the page explaining the visual packing technique, when inspecting field sites and refer to them often.

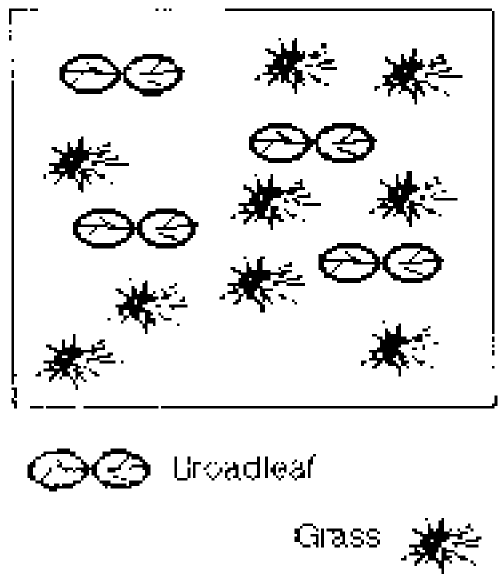
A list of past plantings and a site's maintenance history will help monitoring staff become familiar with a given roadside section and put monitoring efforts where they will be most useful. Develop a plant inventory and maintenance history for each section of roadside, and carry copies when monitoring or applying a treatment. A list of the functional objectives specific to each site inspected will aid in identifying problem vegetation and potential beneficials. This list should be incorporated into the forms used for data collection.

Illustration A5-1

How To Do "Visual Packing"

First, frame an area of vegetation you wish to monitor. Make a note of how you are framing it — the exact size of the frame if you are laying one down, or a description of the frame (i.e., "sighting through passenger window from driver's seat, Ford 150 pickup truck stopped one yard from the edge of the pavement").

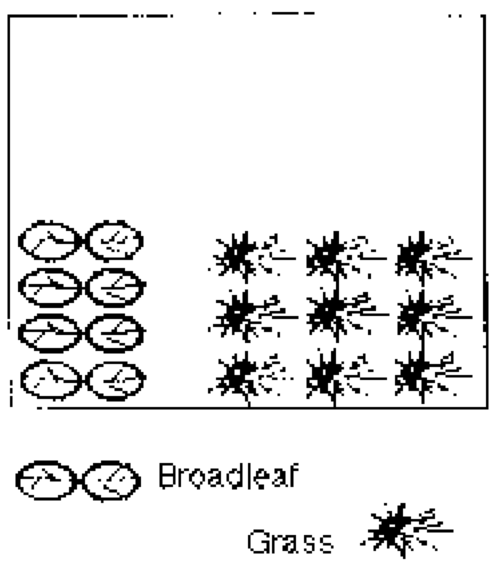
Next, briefly practice visually distinguishing plant species or vegetation types (grasses, shrubs, etc.). Also include patches of bare ground which may provide habitat for problem species in the future. You will notice that individuals or clumps are scattered throughout the framing area, like so:



Visual Packing

Illustration (1)

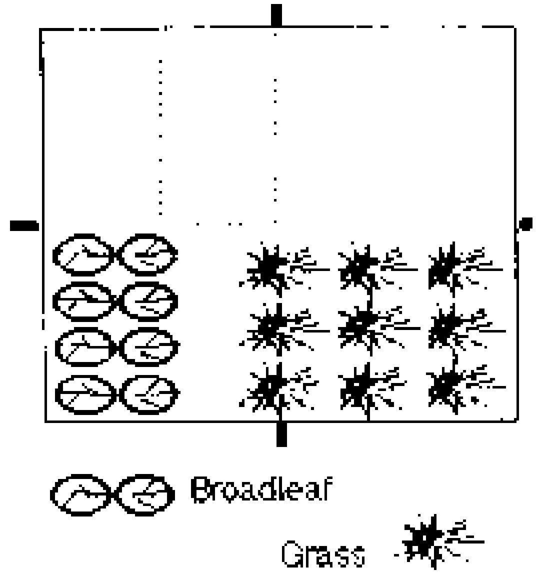
In your mind, gather all of the individuals or clumps of given type you want to categorize and move them into the corner or bottom of the framed area, packing them as close together as possible, like so:



Visual Packing

Illustration (2)

Now draw an imaginary line around the single clump you have created and decide what percentage of the total area that clump represents:



Visual Packing

Illustration (3)

Repeat this process for each species you wish to monitor. Note that marking the frame at the half and quarter area marks helps with estimation. In this example, the dotted lines show subdivisions of the frame area. The visual estimate of broadleaf cover would be about 15 percent of the frame area, while the grasses cover perhaps 25 percent of the frame area. A little practice will make estimates both fast and relatively precise.

14:P:DP/IVM

Appendix 6 Optimizing Record-Keeping

A monitoring program is only as useful as its record-keeping system. Records are the memory of the system and form the basis for making decisions on the most sensible distribution of available resources to the areas most in need of attention or observation.

Without records, whatever is learned is lost as time passes and observations are forgotten. Unwritten memory is unreliable and can lead to erroneous conclusions when comparing effects of treatment or other variables upon the vegetation management problem. When systems lack written records, no learning takes place except that which is transmitted verbally. Verbal transmission alone is prone to error and is seldom verified by quantifiable observations. When people move away or change jobs, their memories go with them and are lost to the system.

What Should the Record Show?

Ideally, records should be kept on the following:

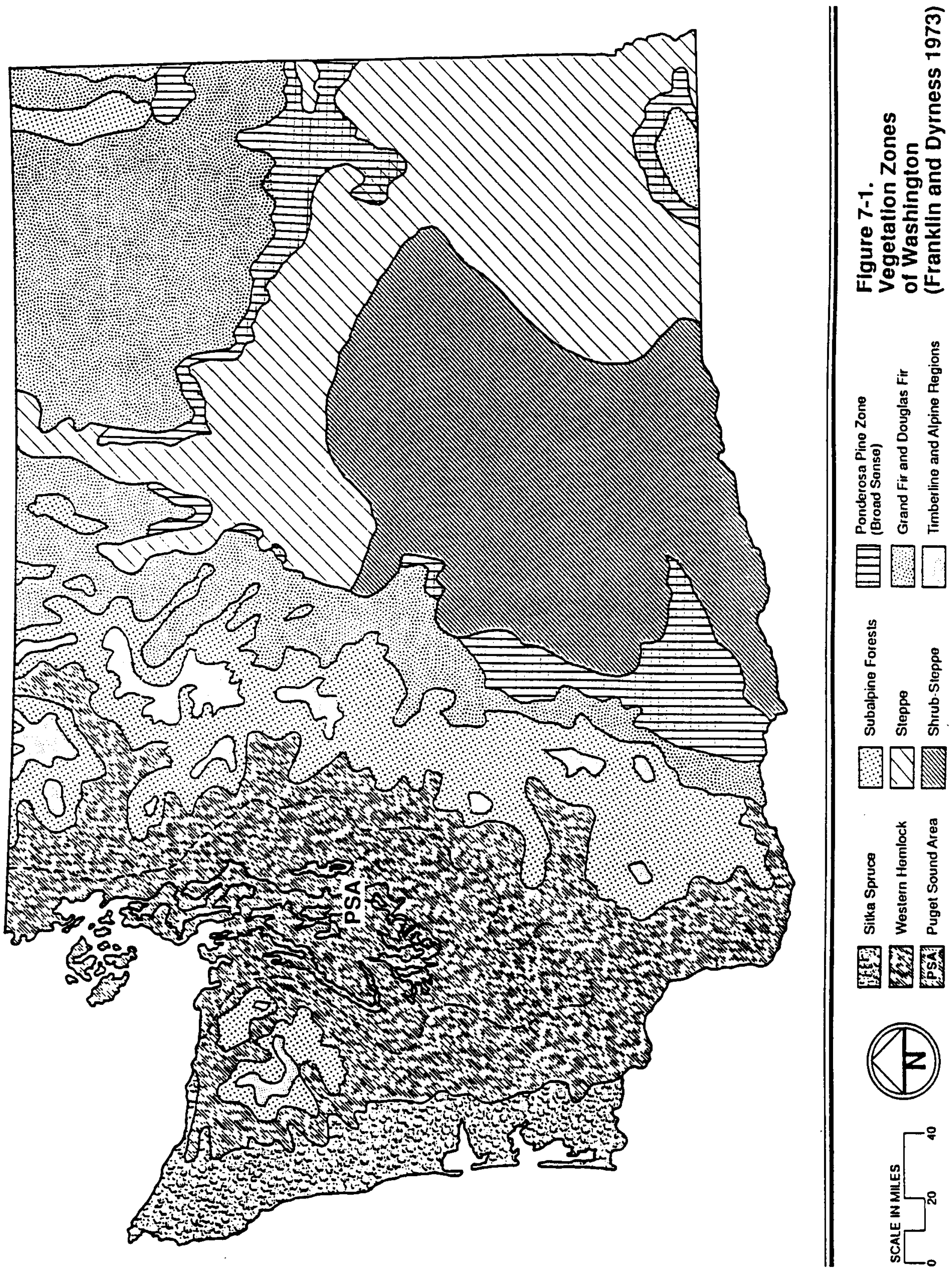
- Location and date of monitoring and the name of the person collecting the data
- Monitoring methods used and the criterion for choosing them
- Type of plants, stage of growth, size
- Identification of the plants (genus, species)
- Condition of the plants (health, vigor)
- How the plants benefit or interfere with functional objectives for the site
- Number or percent cover of the plants
- Distribution of beneficial and problem vegetation (location along roadsides and within zones)
- Seasonal weather patterns
- Information on treatment action (what, where, when, who, how, cost, difficulties)
- Effectiveness of treatment actions (short and long-term effects on problem and beneficial vegetation)

It is desirable to standardize both the format and the process by which the records are kept. This will aid in achieving continuity. A sample form for recording the minimum information needed is provided in **Appendix 1.** Note the extensive use of codes both to speed data collection and to facilitate later entry into a computer program. The form is keyed to a map showing locations along roadside management segments. The Washington State Department of Transportation (WSDOT) will be developing official, standardized forms during development of the Integrated Vegetation Management (IVM) program.

Often, instead of recording numbers, estimates such as “low/medium/high,” or “few/many” can be used. A key on the monitoring form is used to indicate how many organisms, how much cover, or what quantity of any other characteristic (actual or estimated) is represented by the term “low,” etc. Whether numbers or word estimates are used, the important thing is to go out and assess the situation, to do so at regular intervals, and to make some record, no matter how informal, of what is observed.

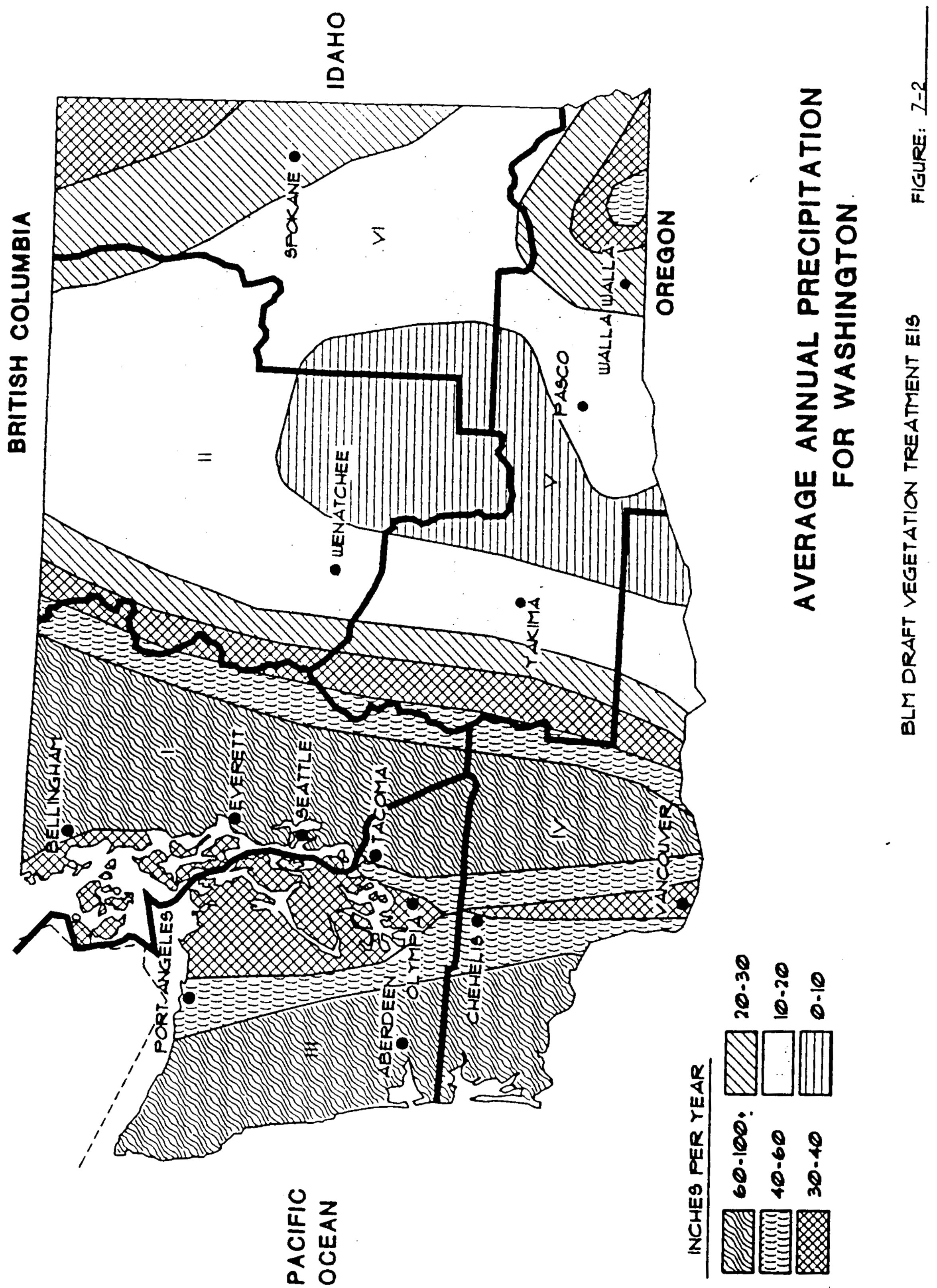
Patterns of change in roadside vegetation and management emerge quickly when data gathered during monitoring is made visual, facilitating decision making. This can be done by hand on graph paper, or by using one of the many graph-making computer programs included in spreadsheet software. Even if staff time and budget constraints limit data evaluation to simply reading through a series of data sheets collected for a site, the data record will allow a rapid and accurate evaluation of where management is needed and which practices are most effective. The use of pie charts to rapidly review vegetation data at various sites is shown in Chapter 3.

15:P:DP/IVM



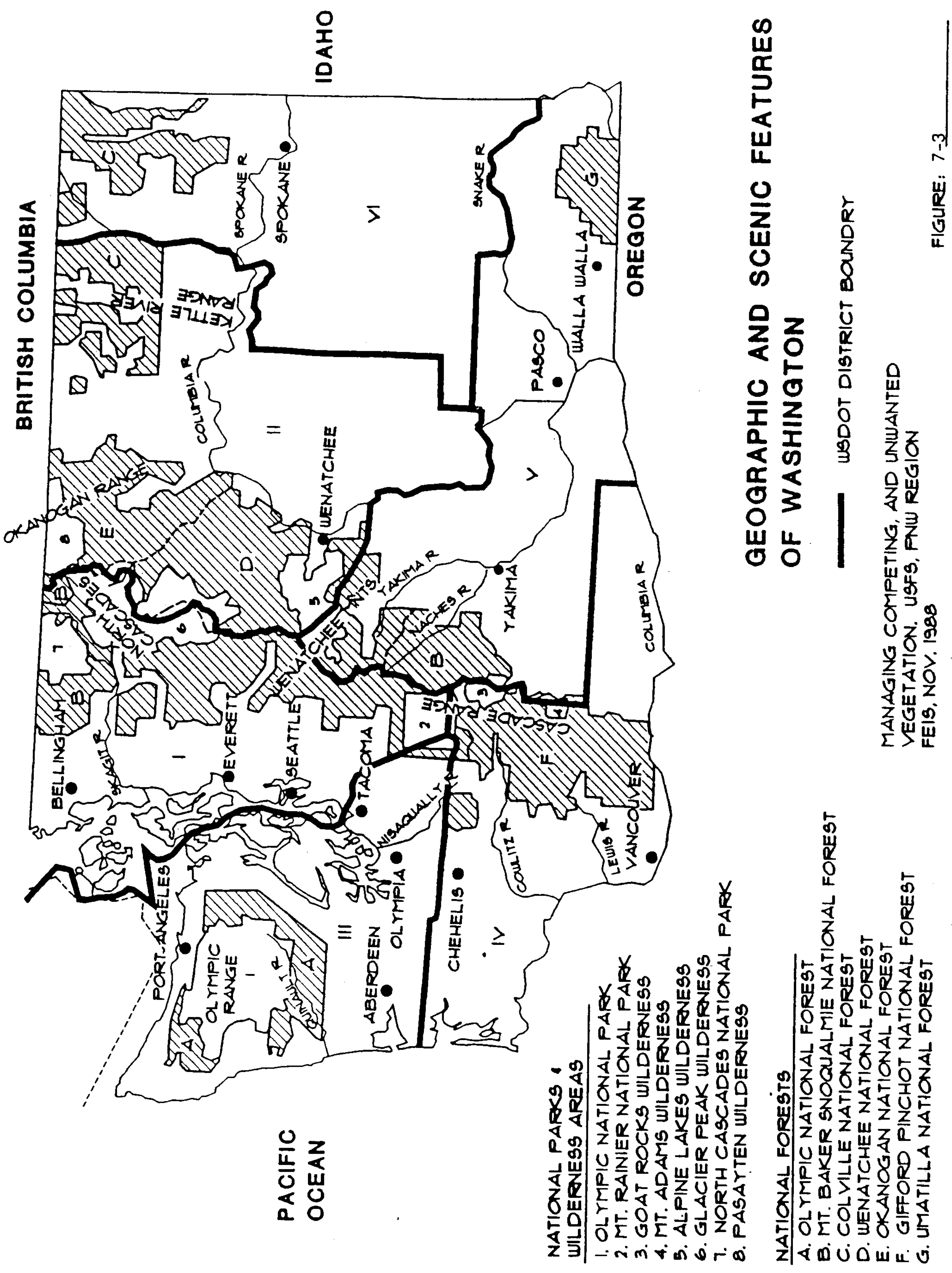
Vegetation Zones of Washington (Franklin and Dyrness, 1973)

Figure 7-1



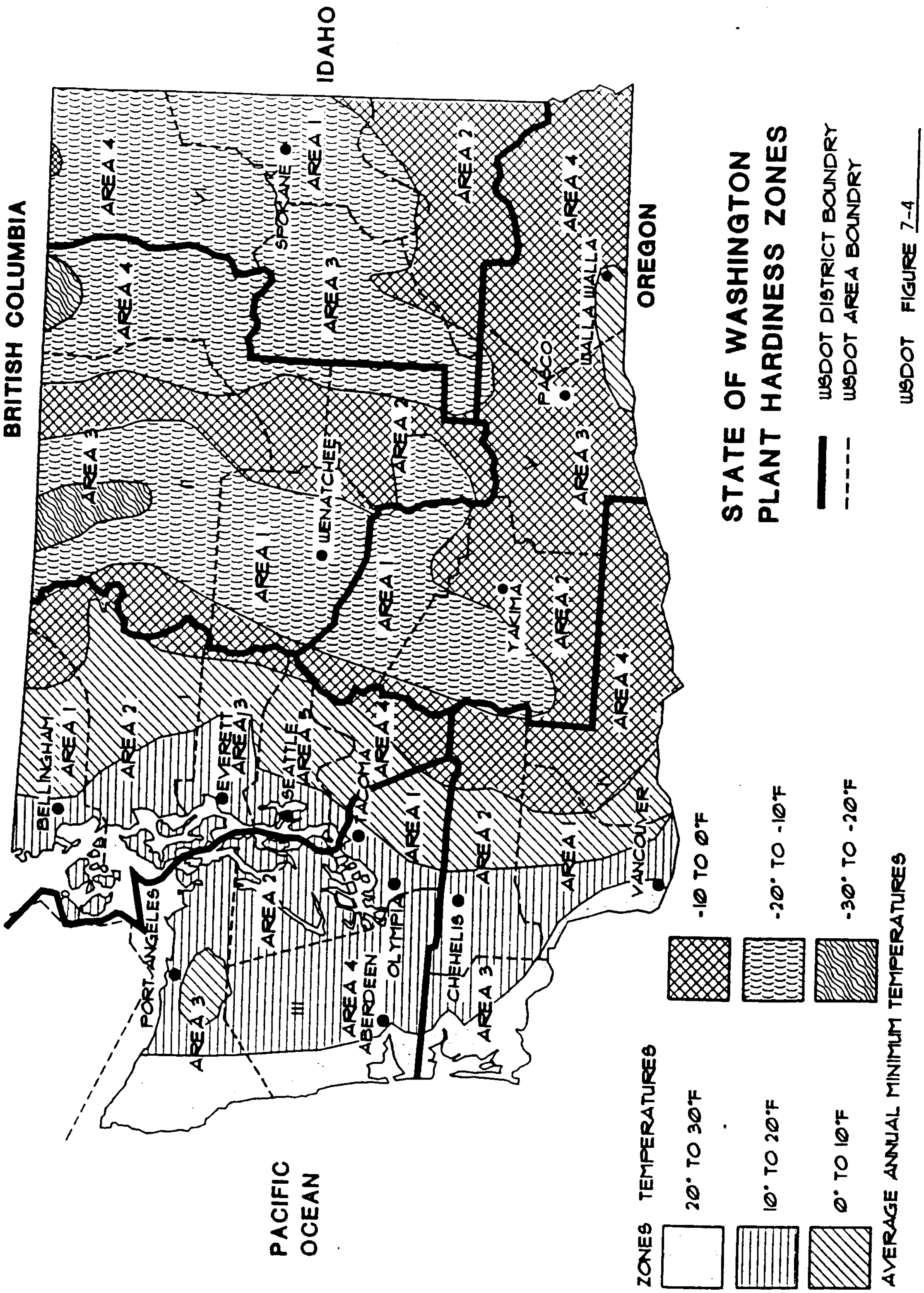
Average Annual Precipitation For Washington

Figure 7-2



Geographic and Scenic Features of Washington

Figure 7-3



State of Washington Plant Hardiness Zones

Figure 7-4

Table 7-1

State listing of Endangered Vascular Plants of Washington

Endangered Vascular Plants of Washington											
Common Name	Scientific Name	Federal Status	Physiographic Province								
Asteraceae			1	2	3	4	5	6	7	8
Wormwood, Northern	*Artemisia campestris* ssp. *borealis* var. *wormskioldii*	Candidate	-	-	-	-	-	-	X	
Boraginaceae										
Stickseed, Showy	*Hackelia venusta*	Candidate	-	-	-	X	-	-	-	-
Brassicaceae										
Yellowcress, Persistentsepal	*Rorippa columbiae*	Candidate	-	-	-	-	X	-	x	-
Campanulaceae										
Howellia	*Howellia aquatilis*	Candidate	-	-	X	-	X	-	X	-
Fabaceae										
Milkvetch, Whited's	*Astragalus sinuatus*	Candidate	-	-	-	X	-	-	-	-
Orchidaceae										
Lady's-slipper, Yellow	*Cypripedium calceolus* var. *parviflorum*	Not Listed	-	-	-	-	-	X	X	-
Twayblade	*Liparis loeselii*	Not Listed	-	-	X	-	X	-	X	-
Polemoniaceae										
Polemonium, Washington	*Polemonium pectinatum*	Candidate	-	-	-	-	-	-	X	-
Ranunculaceae										
Larkspur, White Rock	*Delphinium leucophaeum*	Candidate	-	-	X	-	X	-	-	-
Larkspur, Wenatchee	*Delphinium viridescens*	Candidate	-	-	-	X	X	-	X	-
Scrophulariaceae										
Indian-paintbrush, Golden	*Castellija levisecta*	Candidate	-	-	X	X	X	-	-	-

Table 7-1 (Continued)

State listing of Threatened Vascular Plants of Washington

Threatened Vascular Plants of Washington										
Common Name	Scientific Name	Federal Status	Physiographic Province							
Apiaceae			1	2	3	4	5	6	7	8
Coyote-thistle, Oregon	*Eryngium petiolatum*	Not Listed	-	-	-	-	X	-	X	-
Desert-parsley, Rollins'	*Lomatium rollinsii*	Candidate	-	-	-	-	-	-	X	X
Desert-parsley, Hoover's	*Lomatium tuberosum*	Candidate	-	-	-	-	-	-	X	-
Tauschia, Hoover's	*Tauschia hooveri*	Candidate	-	-	-	X	X	-	-	-
Asteraceae										
Aster, Jessica's	*Aster jessicae*	Candidate	-	-	-	-	-	-	X	X
Eatonella	*Eatonella nivea*	Not Listed	-	-	-	-	-	-	X	-
Daisy, Basalt	*Erigeron basalticus*	Candidate	-	-	-	X	X	-	X	-
Daisy, Howell's	*Erigeron howellii*	Candidate	-	-	-	-	X	-	-	-
Goldenweed, Palouse	*Haplopappus liatriformis*	Candidate	-	-	-	-	-	-	X	-
Microseris, Coast	*Microseris bigelovii*	Not Listed	-	-	X	-	-	-	-	-
Campanulaceae										
Lobelia, Kalm's	*Lobelia kalmii*	Not Listed	-	-	-	-	X	-	X	-
Caryophyleaceae										
Silene, Seely's	*Silene seelyi*	Candidate	-	-	-	X	-	-	-	-
Silene, Spalding's	*Silene spaldingii*	Candidate	-	-	-	-	-	-	X	X
Fabaceae										
Milkvetch, Cotton's	*Astragalus australis* var. *olympicus*	Candidate	X	-	-	-	-	-	-	-
Milkvetch, Columbia	*Astragalus columbianus*	Candidate	-	-	-	X	X	-	X	-

Table 7-1 (Continued)

State listing of Threatened Vascular Plants of Washington

Threatened Vascular Plants of Washington											
Common Name	Scientific Name	Federal Status	Physiographic Province								
Fabaceae			1	2	3	4	5	6	7	8
Milkvetch, Ames'	*Astragalus pulsiferae* var. *suksdorfii*	Candidate	-	-	-	-	-	-	X	-
Lupine, Sabin's	*Lupinus sabinii*	Not Listed	-	-	-	-	-	-	X	X
Lupine, Kincaid's sulfur	*Lupinus sulphureus* var. *kincaidii*	Not Listed	-	-	X	-	X	-	-	-
Clover, Thompson's	*Trifolium thompsonii*	Candidate	-	-	-	X	-	X	X	-
Fumariaceae										
Corydalis, Clackamas	*Corydalis aquae-gelidae*	Candidate	-	-	X	-	X	-	-	-
Hydrophyllaceae										
Phacelia, Sticky	*Phacelia lenta*	Candidate	-	-	-	-	-	X	X	-
Iridaceae										
Blue-eyed grass, Pale	*Sisyrinchium sarmentosum*	Candidate	-	-	-	-	X	-	X	-
Liliaceae										
Onion, Blue Mountain	*Allium dictuon*	Candidate	-	-	-	-	-	-	-	X
Sego-Lily, Long-bearded	*Calochortus longebarbatus* var. *longebarbatus*	Not Listed	-	-	-	-	X	-	X	-
Malvaceae										
Checker-mallow, Hairy-stemmed	*Sidalcea hirtipes*	Candidate	-	-	X	-	X	-	-	-
Checker-mallow, Oregon	*Sidalcea oregana* var. *calva*	Candidate	-	-	-	X	-	-	-	-
Ophioglossaceae										
Adder's tongue	*Ophioglossum vulgatum*	Candidate	X	-	X	X	X	-	X	-

Table 7-1 (Continued)

State listing of Threatened Vascular Plants of Washington

Threatened Vascular Plants of Washington										
Common Name	Scientific Name	Federal Status	Physiographic Province							
Orchidaceae			1	2	3	4	5	6	7	8
Lady's-slipper, Clustered	*Cypripedium fasciculatum*	Not Listed	-	-	-	X	X	-	X	X
Bog-orchid, Choriso	*Plantanthera chorisiana*	Not Listed	-	-	X	X	-	-	-	-
Poaceae										
Reedgrass, Thickglume	*Calamagrostis crassiglumis*	Candidate	X	-	X	X	-	-	-	-
Bluegrass, San Francisco	*Poa unilateralis*	Candidate	-	X	-	-	-	-	-	-
Polemoniaceae										
Navarretia, Marigold	*Navarretia tagetina*	Not listed	-	-	-	-	X	-	X	-
Ranunculaceae										
Buttercup, Obscure	*Ranunculus reconditus*	Candidate	-	-	-	-	X	-	X	-
Rosaceae										
Rockmat, Chelan	*Petrophytum cinerascens*	Candidate	-	-	-	X	-	X	X	-
Raspberry, Northwest	*Rubus nigerrimus*	Candidate	-	-	-	-	-	-	X	-
Saxifragaceae										
Sullivantia, Oregon	*Sullivantia oregana*	Candidate	-	-	-	-	X	-	-	-

Table 7-2

Washington State Sensitive Vascular Plants

Common Name	Scientific Name	Federal Status	Physiographic Province
Alismataceae			
Waterplantain, Fringed	*Machaerocarpus californicus*	Not Listed	6
Apiaceae			
Water-hemlock, Bulb-bearing	*Cicuta bulbifera*	Not Listed	3,4,6
Desert-parsley, Smooth	*Lomatium laevigatum*	Candidate	7
Desert-parsley, Umtanum	*Lomatium quintuplex*	Not Listed	4,5,7
Desert-parsley, Snake Canyon	*Lomatium serpentinum*	Not Listed	7,8
Desert-parsley, Suksdorf's	*Lomatium suksdorfii*	Candidate	7
Sanicle, Bear's-foot	*Sanicula arctopoides*	Not Listed	2
Snake-root, Black	*Sanicula marilandica*	Not Listed	6
Asteraceae			
Agoseris, Tall	*Agoseris elata*	Not Listed	3,4,5,6,7
Pussy-toes, Meadow	*Antennaria corymbosa*	Not Listed	6
Pussy-toes, Nuttall's	*Antennaria parvifolia*	Not Listed	6,7
Aster, White-top	*Aster curtus*	Candidate	3,5
Aster, Rush	*Aster junciformis*	Not Listed	3,5
Aster, Arctic	*Aster sibericus* var. *meritus*	Not Listed	1,3,4,8
Chaenactis, Thompson's	*Chaenactis thompsonii*	Not Listed	4,5
Fleabane, Tall bitter	*Erigeron acris* var. *elatus*	Not Listed	6
Fleabane, Alice's	*Erigeron aliceae*	Not Listed	1
Daisy, Arctic-alpine	*Erigeron humilis*	Not Listed	6
Daisy, Gorge	*Erigeron oreganus*	Not Listed	5
Daisy, Thompson's wandering	*Erigeron peregrinus* ssp. *peregrinus* var. *thompsonii*	Not Listed	1,2
Daisy, Piper's	*Erigeron piperianus*	Not Listed	4,5,7
Microseris, Northern	*Microseris borealis*	Not Listed	1,3,4
Boraginaceae			
Cryptantha, Bristly	*Cryptantha interrupta*	Not Listed	4,5,6,7
Cryptantha, Gray	*Cryptantha leucophaea*	Not Listed	4,5,6,7
Cryptantha, Beaked	*Cryptantha rostellata*	Not Listed	7
Forget-me-not, Pale alpine	*Eritrichium nanum* var. *elongatum*	Not Listed	4,6
Stickseed, Gray	*Hackelia cinerea*	Not Listed	7
Stickseed, Diffuse	*Hackelia diffusa* var. *diffusa*	Not Listed	5,7
Stickseed, Sagebrush	*Hackelia hispida* var. *disjuncta*	Not Listed	6,7
Combseed, Bristly	*Pectocarya setosa*	Not Listed	5,7

Table 7-2 (Continued)
Washington State Sensitive Vascular Plants

Common Name	Scientific Name	Federal Status	Physiographic Province
Brassicaceae			
Rockcress, Cross-haired	*Arabis crucisetosa*	Not Listed	7,8
Scurvygrass	*Cochlearia officinalis*	Not Listed	1,3
Draba, Golden	*Draba aurea*	Not Listed	3,4,6
Draba, Lance-leaved	*Draba cana*	Not Listed	1,6
Draba, Douglas'	*Draba douglasii* var. *douglasii*	Not Listed	5,7
Draba, Long-stalked	*Draba longipes*	Not Listed	1
Peppergrass, Sharpfruited	*Lepidium oxycarpum*	Not Listed	3
Twinpod, Common	*Physaria didymocarpa* var. *didymocarpa*	Not Listed	8
Campanulaceae			
Harebell, Alaska	*Campanula lasiocarpa*	Not Listed	3,4,5,7
Blue-cup, Common	*Githopsis specularioides*	Not Listed	2,3,4,5,7
Lobelia, Water	*Lobelia dortmanna*	Not Listed	1,3,4,5
Crassulaceae			
Pygmy-weed	*Tillaea aquatica*	Not Listed	1,2,3,4,5,6,7
Pygmy-weed, Erect	*Tillaea erecta*	Not Listed	3
Cyperaceae			
Sedge, Bronze	*Carex aenea*	Not Listed	6
Sedge, Yellow-flowered	*Carex anthoxanthea*	Not Listed	1
Sedge, Blackened	*Carex atrata* var. *atrosquama*	Not Listed	6
Sedge, Erect Blackened	*Carex atrata* var. *erecta*	Not Listed	3,4
Sedge, Buxbaum's	*Carex buxbaumii*	Not Listed	1,2,3,4,6
Sedge, Coiled	*Carex circinata*	Not Listed	1
Sedge, Bristly	*Carex comosa*	Not Listed	3,4,5
Sedge, Dense	*Carex densa*	Not Listed	2,7
Sedge, Yellow	*Carex flava*	Not Listed	6,7
Sedge, Porcupine	*Carex hystricina*	*Not Listed*	*5,6,7*
Sedge, Green-fruited	*Carex interrupta*	*Not Listed*	*1,2,3,4,5,7*
Sedge, Large-awn	*Carex macrochaeta*	*Not Listed*	*3,4*
Sedge, Scandinavian	*Carex norvegica*	*Not Listed*	*6*
Sedge, Blunt	*Carex obtusata*	*Not Listed*	*1,3*
Sedge, Few-flowered	*Carex pauciflora*	*Not Listed*	*1,2,3,4,5*
Sedge, Poor	*Carex paupercula*	*Not Listed*	*3,4,6*
Sedge, Several-flowered	*Carex pluriflora*	*Not Listed*	*1,3*
Sedge, Smokey Mountain	*Carex proposita*	*Not Listed*	*4*

Table 7-2 (Continued)
Washington State Sensitive Vascular Plants

Common Name	Scientific Name	Federal Status	Physiographic Province
Sedge, Russet	*Carex saxatilis var. major*	Not Listed	3,4,5,6
Sedge, Canadian Single-spike	*Carex scirpoidea var. scirpoidea*	Not Listed	3,4,6
Sedge, Saw-leaved	*Carex scopulorum var. prionophylla*	Not Listed	4,6
Sedge, Narrow-leaved	*Carex stenophylla*	Not Listed	6
Sedge, Long-styled	*Carex stylosa*	Not Listed	3
Sedge, Many-headed	*Carex sychnocephala*	Not Listed	6
Flatsedge, Shining	*Cyperus rivularis*	Not Listed	5,7
Spike-rush, Beaked	*Eleocharis rostellata*	Not Listed	5,7
Cottongrass, Green-keeled	*Eriophorum viridicarinatum*	Not Listed	6
Ericaceae			
Cassiope, Clubmoss	*Cassiope lycopodioides ssp. cristipilosa*	Not Listed	3,4,5
Snowberry, Creeping	*Gaultheria hispidula*	Not Listed	6
Azalea, Alpine	*Loiseleuria procumbens*	Not Listed	3,4,
Pinesap, Fringed	*Pleuricospora fimbriolata*	Not Listed	2,3,4,5,7
Blueberry, Velvet-leaved	*Vaccinium myrtilloides*	Not Listed	6
Fabaceae			
Milkvetch, Palouse	*Astragalus arrectus*	Not Listed	5,7
Milkvetch, Arthur's	*Astragalus arthuri*	Not Listed	7,8
Milkvetch, Cusick's	*Astragalus cusickii var. cusickii*	Not Listed	7,8
Milkvetch, Geyer's	*Astragalus geyeri*	Not Listed	7
Milkvetch, Least Bladdery	*Astragalus microcystis*	Not Listed	1,3,6,7
Milkvetch, Pauper	*Astragalus misellus var. pauper*	Candidate	4,5,6,7
Milkvetch, Piper's	*Astragalus riparius*	Not Listed	7
Chinquapin, Golden	*Chrysolepis chrysophylla*	Not Listed	1,3,5
Lupine, Prairie	*Lupinus cusickii*	Candidate	7,8
Crazyweed, Columbia	*Oxytropis campestris var. columbiana*	Not Listed	6
Carzyweed, Sticky	*Oxytropis viscida*	Not Listed	1,3
Clover, Douglas	*Trifolium douglasii*	Not Listed	
Clover, Plumed	*Trifolium plumosum var. plumosum*	Not Listed	7
Gentianaceae			
Gentian, Swamp	*Gentiana douglasiana*	Not Listed	1,3,4,5
Gentian, Glaucous	*Gentiana glauca*	Not Listed	3,4,6
Gentian, Slender	*Gentiana tenella*	Not Listed	6
Grossulariaceae			
Current, Squaw	*Ribes cereum var. colubrinum*	Not Listed	7,8

Table 7-2 (Continued)

Washington State Sensitive Vascular Plants

Common Name	Scientific Name	Federal Status	Physiographic Province
Gooseberry, Umatilla	*Ribes oxyacanthoides ssp. cognatum*	Not Listed	6,7,8
Gooseberry, Idaho	*Ribes oxyacanthoides ssp. irriguum*	Not Listed	6,7,8
Hydrophyllaceae			
Phacelia, Franklin's	*Phacelia franklinii*	Not Listed	6
Isoetaceae			
Quillwort, Nuttall's	*Isoetes nuttallii*	Not Listed	3,5,7
Iridaceae			
Blue-eyed Grass	*Sisyrinchium septentrionale*	Not Listed	6
Juncaceae			
Rush, Kellogg's	*Juncus kelloggii*	Not Listed	5,7
Woodrush, Curved	*Luzula arcuata*	Not Listed	5,7
Lamiaceae			
Sage, Wood	*Teucrium canadense ssp. viscidum*	Not Listed	6,7
Lentibulariaceae			
Bladderwort, Flat-leaved	*Utricularia intermedia*	Not Listed	1,3,4
Liliaceae			
Onion, Constricted Douglas'	*Allium constrictum*	Candidate	6,7
Fawn-lily, Pink	*Erythronium revolutum*	Not Listed	1,2,3,5
Lily, Black (Indian Rice)	*Fritillaria camschatcensis*	Not Listed	3,4
Trillium, Small-flowered	*Trillium parviflorum*	Not Listed	3,5
Hellebore, Siskiyou False	*Veratrum insolitum*	Not Listed	5,7
Lycopodiaceae			
Clubmoss, Treelike	*Lycopodium dendroideum*	Not Listed	3,4,6
Clubmoss, Bog	*Lycopodium inundatum*	Not Listed	2,3,4,5
Malvaceae			
Globemallow, Longsepal	*Iliamna longisepala*	Not Listed	4,5,6,7
Onagraceae			
Evening-primrose, Dwarf	*Oenothera pygmaea*	Not Listed	6,7
Ophioglossaceae			
Grape-fern, Lance-leaved	*Botrychium lanceolatum*	Not Listed	1,2,3,4,5,6
Moonwort	*Botrychium lunaria*	Not Listed	1,3,4,5,6
Grape-fern, Victorin's	*Botrychium minganense*	Not Listed	1,3,4,6
Moonwort, Mountain	*Botrychium montanum*	Not Listed	3,4

Table 7-2 (Continued)
Washington State Sensitive Vascular Plants

Common Name	Scientific Name	Federal Status	Physiographic Province
Moonwort, St. John's	*Botrychium pinnatum*	Not Listed	1,3,4,5,6
Grape-fern, Little	*Botrychium simplex*	Not Listed	1,2,4
Orchidaceae			
Helleborine, Giant	*Epipactis gigantea*	Not Listed	1,2,3,4,5,7
Twayblade, Northern	*Listera borealis*	Not Listed	6
Bog-orchid, Small Northern	*Plantanthera obtusata*	Not Listed	3,4,5,6
Bog-orchid, Canyon	*Plantanthera sparsiflora*	Not Listed	5
Ladies-tresses, Western	*Spiranthes romanzoffiana var. porrifolia*	Not Listed	4,5,7
Orobanchaceae			
Broomrape, Pine	*Orobanche pinorum*	Not Listed	6,7
Oxalidaceae			
Oxalis, Western Yellow	*Oxalis suksdorfii*	Not Listed	1,3
Papaveraceae			
Meconella, White	*Meconella oregana*	Not Listed	3,5,7
Plantaginaceae			
Plantain, Alaska	*PLANTAGO MACROCARPA*	Not Listed	1,2,3
Poaceae			
Bentgrass, Northern	*Agrostis borealis*	Not Listed	6
Muhly, Marsh	*Muhlenbergia glomerata*	Not Listed	6
Ricegrass, Henderson's	*Oryzopsis hendersonii*	Not Listed	4,5,7
Bluegrass, Pacific	*Poa gracillima var. multnomae*	Not Listed	5
Bluegrass, Gray's	*Poa grayana*	Not Listed	1,3,4,6
Bluegrass, Loose-flowered	*Poa laxiflora*	Not Listed	2
Bluegrass, Wheeler's	*Poa nervosa var. nervosa*	Not Listed	3,5
Alkaligrass, Alaska	*Puccinellia nutkaensis*	Not Listed	3,4
Cordgrass, Prairie	*Spartina pectinata*	Not Listed	6,7
Polemoniaceae			
Linanthus, Baker's	*Linanthus bakeri*	Not Listed	5,7
Polemonium, Great	*Polemonium carneum*	Not Listed	2,5
Polemonium, Skunk	*Polemonium viscosum*	Not Listed	6
Polygonaceae			
Knotweed, Austin's	*Polygonum austiniae*	*Not Listed*	*7*
Polypodiaceae			
Maiden-hair, Dwarf	*Adiantum pedatum ssp. subpumilum*	Not Listed	1,3

Table 7-2 (Continued)
Washington State Sensitive Vascular Plants

Common Name	Scientific Name	Federal Status	Physiographic Province
Lip-fern, Fee's	*Cheilanthes feei*	Not Listed	7
Rock-brake, Steller's	*Cryptogramma stelleri*	Not Listed	4,6
Sheild-fern, Crested	*Dryopteris cristata*	Not Listed	6
Cliff-brake, Sierra	*Pellaea brachyptera*	Not Listed	4
Cliff-brake, Brewer's	*Pellaea breweri*	Not Listed	1,3,4,5,7
Sword-fern California	*Polystichum californicum*	Not Listed	3,5
Chain-fern	*Woodwardia fimbriata*	Not Listed	1,3,5
Portulacaceae			
Springbeauty, Pacific Lanceleaf	*Claytonia lanceolata var. pacifica*	Not Listed	1
Montia, Branching	*Montia diffusa*	Not Listed	3,4,5,7
Potamogetonaceae			
Pondweed, Blunt-leaved	*Potamogeton obtusifolius*	Not Listed	1,3,4
Primulaceae			
Shooting Star, Few-flowered	*Dodecatheon pulchellum var. watsonii*	Not Listed	3,4,6
Water-pimpernel	*Samolus parviflorus*	Not Listed	2
Ranunculaceae			
Pasque flower	*Anemone nuttalliana*	Not Listed	4,5,7
Ranunculaceae			
Bugbane, Tall	*Cimicifuga elata*	Not Listed	1,3,4,5
Goldthread, Spleenwort-leaved	*Coptis asplenifolia*	Not Listed	1,3,4
Buttercup, Cooley's	*Ranunculus cooleyae*	Not Listed	1,2,3,4
Water-buttercup, Long-beaked	*Ranunculus longirostris*	Not Listed	6
Meadowrue, Purple	*Thalictrum dasycarpum*	Not Listed	6
Rosaceae			
Mountain-avens, Yellow	*Dryas drummondii*	*Not Listed*	*3,4,6*
Queen-of-the-forest	*Filipendula occidentalis*	Not Listed	2
Avens, Water (Purple)	*Geum rivale*	Not Listed	6
Avens, Ross'	*Geum rossi var. depressum*	Not Listed	4
Cinquefoil, Brewer's	*Potentilla breweri*	Not Listed	5,7
Cinquefoil, Diverse-leaved	*Potentilla diversifolia var. perdissecta*	Not Listed	6
Cinquefoil, Snow	*Potentilla nivea*	Not Listed	6
Cinquefoil, Five-leaved	*Potentilla quinquefolia*	Not Listed	6
Nagoonberry	*Rubus acaulis*	Not Listed	6
Burnet, Menzies'	*Sanguisorba menziesii*	Not Listed	1,2,3

Table 7-2 (Continued)
Washington State Sensitive Vascular Plants

Common Name	Scientific Name	Federal Status	Physiographic Province
Spiraea, Subalpine	*Spiraea densiflora var. splendens*	Not Listed	7,8
Rubiaceae			
Bedstraw, Boreal	*Galium kamtschaticum*	Not Listed	1,2
Salicaceae			
Willow, Hoary	*Salix candida*	Not Listed	6
Willow, MacCall's	*Salix maccalliana*	Not Listed	6
Willow, Soft-leaved	*Salix sessilifolia*	Not Listed	3,4,5
Willow, Tweedy's	*Salix tweedyi*	Not Listed	6
Saxifragaceae			
Bolandra, Oregon	*Bolandra oregana*	Not Listed	5
Golden carpet, Northern	*Chrysosplenium tetrandrum*	Not Listed	6
Alumroot, Gooseberry-leaved	*Heuchera grossulariifolia var. tenuifolia*	Not Listed	5,7
Grass-of-Parnassus, Finged	*Parnassia fimbriata var. hoodiana*	Not Listed	5
Grass-of-Parnassus, Kotzebue's	*Parnassia kotzebuei*	Not Listed	6
Grass-of-Parnassus, Northern	*Parnassia palustris var. neogaea*	Not Listed	1,2
Saxifrage, Nodding	*Saxifraga cernua*	Not Listed	6
Saxifrage, Pygmy	*Saxifraga debilis*	Not Listed	1,3,4
Saxifrage, Swamp	*Saxifraga integrifolia var. apetala*	Not Listed	3,4,5,6,7
Scrophulariaceae			
Indian-paintbrush, Obscure	*Castilleja cryptantha*	*Candidate*	*5*
Collinsia, Few-flowered	*Collinsia sparsiflora var. bruciae*	*Not Listed*	*5,7*
Mudwort, Southern	*Limosella acaulis*	*Not Listed*	*2,3,4,7*
False-pimpernel	*Lindernia anagallidea*	*Not Listed*	*1,3,5,7*
Monkey-flower, Pulsifer's	*Mimulus pulsiferae*	*Not Listed*	*5,6,7*
Monkey-flower, Suksdorf's	*Mimulus suksdorfii*	*Not Listed*	*4,7*
Owl clover, Rosy	*Orthocarpus bracteosus*	*Not Listed*	*5,7*
Lousewort, Mt. Rainier	*Pedicularis rainierensis*	*Not Listed*	*3,5,7*
Penstemon, Hot-rock	*Penstemon deustus var. variabilis*	*Not Listed*	*5,7*
Synthyris, Cut-leaf	*Synthyris pinnatifida var. lanuginosa*	*Not Listed*	*1*
Solanaceae			
Tobacco, Coyote	*Nicotiana attenuata*	*Not Listed*	*5,6,7*

Table 7-3

Plants Recommended For Revegetation

Native Plant List

Botanical Name	Common Name	Zone	Remarks
Deciduous Trees			
Acer circinatum	*Vine maple*	*6-9*	
Acer glabrum	*Rocky Mountain maple*	*5-9*	
Acer macrophyllum	*Big leaf maple*	*6-9*	*urban environment*
Alnus rubra	*Red alder*	*6-9*	*roadside, reclamation*
Betula occidentalis	*Water birch*	*5,6*	*wetlands*
Betula papyrifera	*Paper birch*	*5-8*	
Cornus nuttallii	*Pacific dogwood*	*7-9*	*part shade*
Corylus cornuta	*Hazel nut*	*8,9*	*reclamation*
Fraxinus oregona	*Oregon ash*	*7-9*	*roadside wetlands*
Larix occidentalis	*Western larch*	*5-6*	*fast growing*
Populus tremuloides	*Quaking aspen*	*5-7*	*wetlands, reclamation*
Populus trichocarpa	*Black cottonwood*	*5-9*	*roadside, reclamation,*
Prunus emarginata	*Bitter cherry*	*5-9*	
Quercus garryana	*Oregon oak*	*7,8*	*slow growing*
Salix lasiandra	*Pacific willow*	*7-8*	*wetlands, fast growing*
Salix scouleriana	*Scouler willow*	*7-8*	*wetlands, fast growing*
Evergreen Trees			
Abies amabilis	*Pacific silver fir*	*5,6,8,*	
Abies concolor	*White fir*	*4*	*urban environment*
Abies grandis	*Grand fir*	*6-9*	
Abies procera	*Noble fir*	*5,6*	*slow growing*
Abies lasiocarpa	*Alpine fir*	*6,8*	*slow growing*
Arbutus menziesi	*Pacific madrone*	*8,9*	
Castanopsis chrysophylla	*Golden chinquapin*	*8,9*	
Chamaecyparis nootkatensis	*Alaska yellow cedar*	*6,8*	*roadside*
Juniperus scopulorum	*Rocky mt. juniper*	*5,6,8*	*drought/salt tolerant*
Picea engelmanni	*Engelmann spruce*	*6,7*	
Picea sitchensis	*Sitka spruce*	*8,9*	
Pinus contorta 'contorta'	*Shore pine*	*6-9*	*seaside, roadside*
Pinus contorta 'latifolia'	*Lodgepole pine*	*6-9*	*roadside*
Pinus monticola	*Western white pine*	*5-8*	
Pinus ponderosa	*Ponderosa pine*	*5-7*	*fast growing*
Pseudotsuga menziesii	*Douglass fir*	*5-9*	*roadside, fast growing*

Table 7-3 (Continued)

Plants Recommended For Revegetation

Native Plant List

Botanical Name	Common Name	Zone	Remarks
Taxus brevifolia	*Western Yew*	*5-9*	
Thuja plicata	*Western red ceder*	*5-9*	
Tsuga heterophylla	*Western hemlock*	*6-9*	*roadside, fast growing*
Tsuga mertensiana	*Mountain hemlock*	*6,8*	*roadside*
Tall Shrubs/Small Trees 8 to 20 Feet			
Acer circinatum	*Vine maple*	*7-9*	
Alnus sinuata	*Sitka alder*	*7-9*	
Amelachier alnifolia	*Serviceberry*	*6-9*	*roadside*
Celtis reticulata	*Hackberry*	*7*	
Lonicera involucrata	*Black twinberry*	*6-9*	
Myrica californica	*California wax myrtle*	*8,9*	
Oemleria cerasiformis	*Indian Plum*	*8,9*	
Physocarpus capitatus	*Ninebark*	*6,9*	
Rhamnus purshiana	*Cascara shrub*	*5-8*	*non-pollution tolerant*
Rhododendron macrophyllum	*Pacific rhododendron*	*7-9*	*state flower*
Rhus glabra	*Smooth sumac*	*5,6*	*fast growing*
Ribes sanguineum	*Red flowering current*	*8,9*	*roadside*
Salix discolor	*Pussywillow*	*6-9*	*wetlands*
Salix scouleriana	*Scouler willow*	*7-8*	*wetlands, fast growing*
Sambucus cerulea	*Elderberry*	*5-7*	
Sambucus racemosa	*Elderberry*	*5-7*	
Sorbus scopulina	*Western mt. ash*	*5-7*	
Sorbus sitchensis	*Sitka mt. ash*	*5,6*	
Large Shrubs 5 to 8 Feet High			
Arctostaphylos columbiana	*Hairy manzanita*	*7-9*	*roadside*
Cornus stolonifera	*Redosier dogwood*	*7*	*wetlands, urban environment*
Holodiscus discolor	*Oceanspray*	*5-8*	*roadside*
Philadelphus lewisii	*Mock-orange*	*5,6,9*	*fast growing*
Rubus spectabilis	*Salmon berry*	*8,9*	
Vaccinium parvifolium	*Red huckleberry*	*8,9*	
Viburnum opulus	*Highbush cranberry*	*7*	

Table 7-3 (Continued)

Plants Recommended For Revegetation

Native Plant List

Botanical Name	Common Name	Zone	Remarks
Native Medium Shrubs 3 to 5 Feet High			
Adiantum pedatum	*Maidenhair fern*	*7-9*	
Andromeda polifolia	*Bog rosemary*	*5,6*	*bogs*
Arctostaphylos media	*Media manzanita*	*8,9*	
Athyrium filix-femina	*Lady fern*	*7-9*	
Gaultheria shallon	*Salal*	*7-9*	*roadside*
Mahonia aquifolium	*Oregon grape*	*5-9*	*roadside*
Potentilla fruticosa	*Shrubby cinquefoil*	*5-8*	*roadside*
Rosa nutkana	*Wild rose*	*6-8*	
Rosa woodsii	*Wild rose*	*6-8*	
Rubus parviflorus	*Thimbleberry*	*7-9*	
Shepherdia canadensis	*Buffalo berry*	*6,7,*	*roadside*
Spirea douglasii	*Hardhack*	*8,9*	
Low Shrubs 18 Inches to 3 Feet High			
Blechnum spicant	*Deer fern*	*7-9*	
Mahonia repens	*Low Oregon grape*	*5-9*	*roadside*
Mahonia nervosa	*Creeping Oregon grape*	*5-9*	*roadside*
Polystichum munitum	*Sword fern*	*7-9*	
Symphoricarpos albus	*Snowberry*	*7-9*	
Native Ground Covers to 18 Inches High			
Arctostaphylos uva-ursi	*Kinnikinnick*	*4-9*	*roadside*
Asarum caudatum	*Wild ginger*	*7-9*	
Cornus canadensis	*Bunchberry*	*6,7*	*urban environment*
Dicentra formosa	*Western bleeding heart*	*8,9*	
Fragaria chiloensis	*Evergreen strawberry*	*5-9*	
Juncus effusus	*Soft rush*	*6-8*	
Lupinus spp.	*Lupine*	*5-6*	
Lysichitum americanum	*Skunk cabbage*	*8,9*	*wetlands*
Maianthemum dilatatum	*False lily of the valley*	*9*	
Oxalis oregona	*Wood sorrel*	*8,9*	
Rubus ursinus	*Westn blackberry*	*5-9*	
Trillium ovatum	*Trillum*	*9*	
Trifolium repens	*White clover*	*6-8*	*roadside*

Table 7-3 (Continued)

Plants Recommended For Revegetation

Ornamental Plant List

Botanical Name	Common Name	Zone	Remarks
Deciduous Trees			
Acer buergerianum	*Trident maple*	*4-9*	*roadside*
Acer campestre	*Hedge maple*	*4-8*	*roadside*
Acer ginnala	*Amur maple*	*5-9*	
Acer glabrum	*Rocky mt. maple*	*6*	
Acer palmatum	*Japanese maple*	*6-9*	
Acer platanoides	*Norway maple*	*4-9*	*street trees*
Acer pseudoplatanus	*Sycamore maple*	*4-7*	
Acer rubrum	*Red maple*	*4-9*	*street trees*
Acer saccharum	*Sugar maple*	*4-9*	*street tree*
Aesculus carnea	*Red horsechestnut*	*4-9*	*street tree*
Aesculus hippocastanum	*Horsechestnut*	*4-9*	
Albizzia julibrissin	*Silk tree*	*8,9*	
Betula pendula	*European white birch*	*4-9*	
Carpinus betulus	*Hornebeam*	*4-7*	*hedges*
Castanea mollissima	*Chinese chestnut*	*4-8*	
Castanea sativa	*Spanish chestnut*	*5*	
Catalpa bignoides	*Southern catalpa*	*5-9*	
Cercidiphyllum japonicum	*Katsura tree*	*4-8*	*street trees*
Cercis canadensis	*Eastern Redbud*	*6-9*	*street trees*
Chrysolarix amabilis	*Golden larch*	*7-9*	
Cladrastis lutea	*American yellowwood*	*6-9*	
Cornus kousa	*Kousa dogwood*	*5-8*	
Cornus mas	*Cornelian cherry*	*4-8*	
Cotinus coggygria	*Smoke tree*	*6-9*	
Crataegus lavallei	*Lavalle hawthorn*	*5-9*	
Crataegus oxyacantha	*English hawthorn*	*5-9*	
Crataegus phaenopyrum	*Washington hawthorn*	*5-9*	
Fagus sylvatica	*European beech*	*5-9*	
Fraxinus ornus	*Flowering ash*	*5,6*	*street tree*
Fraxinus oxycarpa	*Flame ash*	*5-8*	
Ginko biloba	*Maindenhair tree*	*5-9*	*pollution*
Gleditsia tricanthos inermis	*Thornless honeylocust*	*4-9*	*street tree*
Koelreteria paniculata	*Goldenrain tree*	*6-9*	*street trees*
Liquidambar styraciflua	*Sweetgum tree*	*6-9*	*street tree*

Table 7-3 (Continued)

Plants Recommended For Revegetation

Ornamental Plant List

Botanical Name	Common Name	Zone	Remarks
Liriodendron tulipfera	*Tulip tree*	*5-9*	*street tree*
Magnolia kobus	*Kobus magnolia*	*4*	
Magnolia macrophylla	*Bigleaf magnolia*	*5-8*	
Magnolia soulangiana	*Saucer magnolia*	*6-9*	
Malus floribunda	*Japanese flowering crabapple*	*4-9*	
Metasequoia glyptostroboides	*Dawn redwood*	*4-8*	*street tree*
Nyssa sylvatica	*Sour gum, Tupelo*	*4-9*	*non-pollution tolerant*
Oxydendrum arboreum	*Sourwood*	*5-9*	
Platanus acerifolia	*London plane tree*	*6-9*	*highway*
Populus nigra Italica	*Lombardy popular*	*4-9*	
Prunus serrulata	*Japanese flowering cherry*	*7-9*	*street tree*
Prunus subhirtella	*Higan cherry*	*7-9*	*street tree*
Prunus yedoensis	*Yoshino cherry*	*6-9*	
Pyrus calleryana	*Ornamental pear*	*4-8*	*street tree*
Quercus coccinea	*Scarlet oak*	*4-9*	*street tree*
Quercus palustris	*Pin oak*	*5-9*	*wetlands*
Quercus robur	*English oak*	*4-8*	
Quercus rubra	*Northern red oak*	*6*	*street tree*
Sophora japonica	*Pagoda tree*	*4-8*	*roadside*
Sorbus aucuparia	*Euopean Mt. ash*	*4-7*	
Styrax japonica	*Japanese snowbell*	*7-9*	*street tree*
Styrax obassia	*Fragrant snowbell*	*5*	
Tilia americana	*American linden*	*4-9*	*hardy*
Tilia cordata	*Little leaf linden*	*4-9*	*street tree*
Evergreen Trees			
Arbutus unedo	*Strawberry tree*	*7*	
Calocedrus decurrens	*Incense cedar*	*5-8*	
Cedrus atlantica	*Atlas cedar*	*7-9*	
Cedrus deodara	*Deodar cedar*	*7-9*	*street tree*
Chamaecyparis lawsoniana	*Port Orford cedar*	*5-7-*	
Chamaecyparis obtusa	*Hinoki cypress*	*5-8*	
Chamaecyparis pisifera	*Sawara cypress*	*4-8*	
Cryptomeria japonica	*Japanese cryptomeria*	*7-9*	*street tree*
Cupressocyparis leylandii	*Leyland falsecypress*	*6-9*	

Table 7-3 (Continued)

Plants Recommended For Revegetation

Ornamental Plant List

Botanical Name	Common Name	Zone	Remarks
Lithocarpus densiflora	*Tanbark oak*	*8-9*	
Pinus aristata	*Bristlecone pine*	*4-7*	
Pinus densiflora	*Japanse red pine*	*4-7*	
Pinus mugo	*Swiss mountain pine*	*4-7*	
Pinus nigra	*Austrian pine*	*4-9*	*windbreak*
Pinus strobus	*Eastern White pine*	*4-8*	
Pinus sylvertris	*Scots pine*	*4-7*	
Pinus thumbergiana	*Japanese black pine*	*5-7*	
Prunus laurocerasus	*English laurel*	*6*	*hedge*
Sequoiadendron giganteum	*Giant sequoia*	*6*	
Sequoia sempervirens	*Western redwood*	*7*	
Taxus baccata	*English yew*	*6,7*	*hedge*
Thuja occidentalis	*Eastern Arborvitae*	*4-8*	*hedge*
Tsuga canadensis	*Eastern hemlock*	*4-7*	
Zelkova serrata	*Sawleaf Zelkova*	*5-8*	*street tree*
Tall Shrubs 8 to 20 Feet			
Arctostaphylos manzanita	*Common manzanita*	*7-9*	
Buxus sempervierens	*Common box*	*8,9*	
Forsythia intermedia	*Forsythia*	*6-9*	*erosion control*
Ilex crenata	*Japanese holly*	*8,9*	*hedge*
Juniperus chinensis	*Chinese juniper*	*4-9*	
Ligustrum japonicum	*Japanese privet*	*8,9*	
Magnolia stellata	*Star magnolia*	*6-9*	
Photinia fraseri	*Photina*	*7-9*	*hedge*
Photinia serrulata	*Chinese photina*	*8,9*	*hedge*
Prunus lusitanica	*Portuguese laurel*	*8,9*	
Pyracantha coccinea	*Firethorn*	*5-9*	*hedge*
Rhododendron sp.	*Rhododendrons*	*7-9*	
Syringa vulgaris	*Common lilac*	*4-9*	
Viburnum opulus	*European cranberry*	*4-9*	*screening*
Viburnum plicatum 'tomentosum'	*Doublefile viburnum*	*6-9*	
Viburnum rhytidophyllum	*Leatherleaf viburnum*	*8,9*	*screening*

Table 7-3 (Continued)

Plants Recommended For Revegetation

Ornamental Plant List

Botanical Name	Common Name	Zone	Remarks
Large Shrubs 5 to 8 Feet High			
Abelia gradiflora	*Glossy abelia*	*7-9*	
Abelia 'Edward Goucher'	*Goucher abelia*	*7-9*	
Berberis darwini	*Darwin barberry*	*8,9*	
Berberis julianae	*Wintergreen barberry*	*7-9*	*hedge*
Ceanothus griseus	*Carmel ceanothus*	*7,8*	
Ceanothus impressus	*Santa Barbara ceanothus*	*8,9*	
Chaenomeles lagenaria	*Flowering quince*	*5-9*	
Large Shrubs 5 to 8 Feet High			
Cotoneaster parneyi	*Parney cotoneaster*	*8,9*	
Enkianthus campanulatus	*Enkianthus*	*4-9*	
Erica arborea	*Tree heath*	*7*	
Escallonia rubra	*Red escallonia*	*8,9*	
Euonymous alatus	*Winged euonymous*	*4-9*	*hedge*
Euonymous japonicus	*Evergreen euonymous*	*8,9*	
Kalmia latifolia	*Mountain laurel*	*8,9*	
Kerria japonica	*Japanese kerria*	*5-9*	*highway*
Nandina domestica	*Nandina bamboo*	*7-9*	
Osmanthus heterophyllus	*Holly osmanthus*	*8,9*	*hedge*
Pieris floribunda	*Chinese pieris*	*5-8*	
Pieris japonica	*Lily of the valley shrub*	*5-8*	
Pyracantha sp.	*Firethorn*	*8,9*	
Rhododendron sp.	*Rhododendrons*	*7-9*	
Rhus typhinia	*Staghorn sumac*	*4-9*	*highways*
Spiraea vanhouttei	*Vanhoutte spirea*	*4-9*	
Stanvaesia davidiana	*stranvaesia*	*8,9*	
Viburnum burkwoodi	*Burkwood viburnum*	*6-9*	*pollution tolerant*
Viburnum tinus	*Laurestinus viburnum*	*8,9*	*hedge*
Viburnum tomentosum 'plicatum'	*Doublefile virburnum*	*6-9*	
Weigela florida	*Old-fashioned weigela*	*5-9*	*pollution tolerant*

Table 7-3 (Continued)

Plants Recommended For Revegetation

Ornamental Plant List

Botanical Name	Common Name	Zone	Remarks
Medium Shrubs 3 to 5 Feet High			
Acer palmatum 'Disectum'	*Laceleaf maple*	*6-9*	
Berberis thunbergi	*Japanese barberry*	*4-9*	*hedge*
Berberis thunbergi atropurpurea	*Redleaf Japanese barberry*	*4-9*	*hedge*
Berberis verruculosa	*Warty barberry*	*6-9*	
Buxus sempervierens	*Common box*	*6-9*	
Cotoneaster micophylla	*Cotoneaster*	*8,9*	*erosion control*
Euonymous fortunei	*Euonymous*	*6-9*	*wet conditions*
Ilex crenata 'Convexleaf'	*Convexleaf Japanese Holly*	*7-9*	*hedges*
Juniperus chinensis 'Pfitzers'	*Pfitzer juniper*	*4-9*	*drought tolerant*
Medium Shrubs 3 to 5 Feet High			
Pinus mugo	*Dwarf mugo pine*	*6*	*street tree*
Prunus laurocerasus 'zabeliana'	*Zabel laurel*	*7-9*	
Rhododendron hybrids	*Rhododendrons*	*7-9*	
Spiraea bumalda	*Spirea*	*5-9*	
Spiraea thunbergi	*Thunberg spirea*	*5-9*	
Low Plants 18 Inches to 3 Feet High			
Calluna vulgaris	*Heather*	*7-9*	
Cotoneaster horizontalis	*Rock cotoneaster*	*6-9*	
Juniperus chinensis 'sargenti'	*Sargents chinese juniper*	*4-9*	
Juniperus sabina 'tamariscifolia'	*Juniper tam*	*5-9*	
Rhododendron hybrids	*Rhododendrons*	*6-9*	
Spiraea bumalda 'Anthony Waterer'	*Anthony Waterer spiraea*	*4-9*	
Viburnum davidi	*David viburnum*	*7-9*	
Ground covers to 18 Inches High			
Ajuga reptans	*Carpet bugle*	*5-9*	*street tree*
Akebia quinata	*Five leaf akebia*	*5*	*street tree*
Alyssum saxatile	*Goldentuft alyssum*	*4-9*	
Calluna vulgaris	*Golden Scotch heather*	*7-9*	
Campsis radicans	*Trumpet vine*	*5*	
Clematis sp.	*Clamatis*	*5*	
Cotoneaster adprescus	*creeping cotoneaster*	*5*	
C. dammeri	*bearberry cotoneaster*	*6-9*	*eroision*
Erica carnea hybrids	*Heather*	*6-9*	

Table 7-3 (Continued)

Plants Recommended For Revegetation

Ornamental Plant List

Botanical Name	Common Name	Zone	Remarks
Erica darleyensis	*Darley heath*	*7-9*	
Euonymous fortunei hybrids	*Creeping euonymous*	*5-9*	*erosion control*
Festuca ovina glauca	*Blue fescue*	*4-9*	*highway*
Gaultheria procumbens	*Wintergreen*	*3-7*	
Hedera helix hybrids	*Ivy varieties*	*6-9*	
Iberis semmpervirens	*Evergreen candytuft*	*5-9*	
Juniperus horizontalis hybrids	*Creeping junipers*	*4-9*	*drought tolerant*
Pachysandra terminalis	*Japanese pachysandra*	*5-9*	
Parthenocissus quinquefolia	*Virginia creeper*	*5*	
Parthenocissus tricuspidata	*Boston Ivy*	*5*	
Santolina chamaecyparissus	*Lavender cotton*	*8,9*	
Ground Covers to 18 Inches High			
Sarcococca hookeriana humilis	*Sarcococca*	*7-9*	*pollution tolerant*
Vinca minor	*Common periwinkle*	*5-9*	

Table 7-3 (Continued)

Plants Recommended For Revegetation

Grass Seed List

Botanical Name	Common Name	West, WA	East, WA	Remarks
Grass Seed For Roadside Planting				
Acrisatum	*Crested wheat grass*		*x*	
Agropyron elongatum	*Tall wheat grass*	*x*		*wildlife, erosion control*
Agropyron smithii	*Western wheat grass*		*x*	
Agropyron intermedium	*Intermediate wheat grass*	*x*	*x*	*stabilize waterways*
Agrostis temmuis	*Colonial bent grass*		*x*	*high erosion control*
Agrostis tenuis	*Highland astoria colonial bent grass*	*x*		*cut and fill*
Alodecurus pratensis	*Meadow foxtail*	*x*	*x*	*wetlands*
Bromus marginatus	*Mountain broom*	*x*		
Dactylis glomerata	*Orchard grass*	*x*		*wildlife, erosion control*
Festuca arundinacea	*Tall fescue*	*x*	*x*	*wildlife, erosion control; mowed*
Festuca ovina	*Sheep or hard fescue*	*x*	*x*	
Festuca rubra	*Red fescue*	*x*		*high eroison*
Festuca rubra commutata	*Chewings fescue*	*x*		*erosion control*
Lolium multiflorum	*Annual rye*	*x*		*erosion control*
Lolium perenne	*Perennial rye grass*	*x*		*high erosion control*
Phleum villosa	*Timothy*	*x*		*wetlands*
Poa pratensis	*Kentucky blue grass*	*x*		*erosion control*
Trifolium pratense	*Red clover*	*x*	*x*	*erosion control*
Trifolium repens	*White Dutch clover*	*x*		*nitrogen fixing*

Table 7-3 (Continued)

Plants Recommended For Revegetation

Wildflower Seed List

Botanical Name	Common Name	West, WA	East, WA	Remarks
Wildflower Seed For Roadside Plantings				
Amillefolium	*White yarrow*		*x*	*dry areas*
Alyssum compactum	*Alyssum*	*x*	*x*	
Alyssum maritimum	*Alyssum*	*x*	*x*	
Alyssum procumbens	*Alyssum*	*x*	*x*	
Alyssum saxatile	*Alyssum*	*x*	*x*	
Anemone coronaria	*Anemone*	*x*		*native*
Anemone novae-angliae	*New England aster*	*x*		*dry areas*
Anemone pulsatilla	*Anemone*	*x*		
Antirrhinum spp.	*Snapdragon*	*x*	*x*	
Aquilegia spp.	*Columbine*	*x*	*x*	*moist areas*
Aubrietia deltoides	*Aubrietia*	*x*		
Calendula officinalis	*Calendula*	*x*		
Callistephus chinensis	*Aster*	*x*		*except Popon, Powderpuff and Princess types.*
Campanula medium calycanthema	*Cup and Saucer bellflower*	*x*		
Campanula carpatica	*Carpathian bellflower*	*x*		
Campanula medium	*Canterbury bells*	*x*		
Campanula persicifolia	*Peach bellflower*	*x*		
Celosia argentea	*Celosia*	*x*		
Centaurea americana	*Basket flower*		*x*	
Centaurea candidissima	*Dusty miller*		*x*	
Centaurea cyanus	*Cornflower*		*x*	*dry areas*
Centaurea gymnocarpa	*Velvet Centaurea*		*x*	
Centaurea imperialis	*Royal centaurea*		*x*	
Centaurea moschata	*Sweet sultan*		*x*	
Cerastium biebersteinii	*Snow in summer*	*x*	*x*	
Cheiranthus allioni	*Wallflower*	*x*	*x*	*moist areas*
Cynoglossum amabile	*Chinese forget-me-not*	*x*		
Chrysanthemum carinatum	*Painted daisy*	*x*		
Chrysanthemum coronarium	*Chrysanthemum*	*x*	*x*	
Chrysanthemum maximum	*Shasta daisy*	*x*	*x*	
Chrysanthemum segetum	*Chrysanthemum*	*x*	*x*	

Table 7-3 (Continued)

Plants Recommended For Revegetation

Wildflower Seed List

Botanical Name	Common Name	West, WA	East, WA	Remarks
Clarkia elegans	*Clarkia*	x		
Cleome gigantea	*Cleome*	x	x	
Cobaea scandens	*Cathedral bells*	x		
Coix lacrtmajobi	*Job's tears*			
Coreopsis bicolor	*Calliopsis*	x		
Coreopsis drummondi	*Calliopsis*	x		
Coreopsis elegans	*Calliopsis*	x		
Coreopsis lanceolata	*Coreopsis*	x		*moist areas*
Coreopsis tinctoria	*Plains Coreopsis*		x	*dry areas*
Cosmos bipinnatus	*Cosmos*			
Datura arborea	*Angels trumpet*	x		
Delphinium ajacis	*Larkspur*	x	x	*moist areas*
Delphinium cardinale	*Cardinal larkspurx*	x		
Delphinium elatum	*Pacific giant*	x	x	
Dianthus allwoodi	*Sweet wivelsfield*			
Dianthus barbatus	*Sweet william*	x	x	
Dianthus caryophyllus	*Carnation*			
Dianthus chinensis	*China pinks*			
Dianthus. deltoides	*Maiden pinks*	x	x	*roadside*
Dianthus plumarius	*Grass pinks*			
Dimorphotheca	*African daisy*		x	*dry areas aurantiaca*
Dracaena indivisa	*Dracaena*	x	x	
Eschscholzia californica	*California poppy*	x	x	*dry areas*
Gaillardia grandiflora	*Gaillardia*		x	
Gaillardia picata	*Gaillardia*		x	
Gaillardia pulchella	*Gaillardia*		x	*dry areas*
Geum spp.	*Geum*			
Gilia capita	*Globe gilia*	x	x	*dry areas*
Gilia tricolor	*Birds eyes*	x		
Godetia amoena	*Godetia*	x		
Godetia Grandiflora	*Godetia*	x		
Helianthus spp.	*Sunflower*	x	x	*dry areas*
Helishrysum montrosum	*Helichrysum*	x		
Heuchera sanguinea	*Coral bells*	x	x	*native*

Table 7-3 (Continued)

Plants Recommended For Revegetation

Wildflower Seed List

Botanical Name	Common Name	West, WA	East, WA	Remarks
Iberis amara	*Candytuft*		*x*	
Iberis gibraltarica	*Candytuft*	*x*	*x*	
Iberis sempervirens	*Candytuft*	*x*	*x*	
Iberis umbellata	*Candytuft*	*x*	*x*	*moist areas*
Impatiens balsamina	*Balsam*	*x*		
Ipomoea noctiflora	*Moonflower*			
Ipomoea quamoclit	*Cypress vine*			
Lantana camara	*Lantana*	*x*	*x*	
Lantana hybrida	*Lantana*	*x*	*x*	
Linaria maroccana	*Spurred snapdragon*		*x*	*dry areas*
Lobelia erinus	*Lobelia*	*x*	*x*	
Lunaria annua	*Lunaria*	*x*		
Lupinus perennis	*Lupine*		*x*	*dry areas*
Mathiola bicornis	*Stocks*	*x*		
Mathiola incana	*Stocks*	*x*		
Mirabilis jalapa	*Marvel of Pera*			
Myosotis alpestris	*Myosotis*	*x*	*x*	
Myosotis oblongata	*Myosotis*	*x*		
Myosotis palustris	*Myosotis*	*x*		
Nemesia spp.	*Nemesia*	*x*		
Nemophila insignis	*Nemophila*	*x*		
Nicotiana affinis	*Nicotiana*	*x*		
Nicotiana sanderae	*Nicotiana*	*x*		
Nicotiana sylvestris	*Nicotiana*	*x*		
Nierembergia spp.	*Nierembergia*	*x*		
Nigella damascena	*Nigella*	*x*		
Papaver glaucum	*Tulip poppy*	*x*	*x*	
Papaver nudicaule	*Iceland poppy*	*x*	*x*	*full sun*
Papaver Orientalis	*Oriental poppy*	*x*	*x*	
Papaver rhoeas	*Sirley poppy*	*x*	*x*	*dry areas*
Penstemon barbatus	*Penstemon*	*x*	*x*	
Penstemon grandiflorus	*Penstemon*	*x*	*x*	
Penstemon laevigatus	*Penstemon*	*x*	*x*	
Penstemon pupescens	*Penstemon*	*x*	*x*	

Table 7-3 (Continued)

Plants Recommended For Revegetation

Wildflower Seed List

Botanical Name	Common Name	West, WA	East, WA	Remarks
Phacelia campanularia	*California Blue bell*		x	dry areas
Phacelia minor	*Phacelia*		x	
Phacelia tanacetifolia	*Phacelia*		x	
Phlox drummondi	*Phlox*	x	x	
Physalis spp.	*Physalis*	x		
Portulaca gradiflora	*Portulaca*	x		
Reseda odorata	*Mignonette*			
Salpiglossis gloxinaeflora	*Salpiglossis*	x		
Salpiglossis sinuata	*Salpigglossis*	x		
Salvia farinacea	*Mealycup sage*	x	x	
Salvia splendens	*Scarlet sage*	x	x	
Sanvitalia procumbens	*Creeping zinnia*	x		
Saponaria ocymoides	*Saponaria*	x		
Saponaria vaccaria	*Saponaria*	x		
Scabiosa atropurpurea	*Annualal Scabiosa*	x		
Scabiosa caucasica	*Perennial Scabiosa*	x		
Schizanthus spp.	*Schizanthus*	x		
Solanum spp.	*Solanum*	x		
Tagetes spp.	*Marigold*	x	x	
Thunbergia alata	*Thunbergia*	x	x	
Tithonia speciosa	*Torch flower*	x		
Tropaeolum spp.	*Nasturtium*	x		
Verbena hybrida	*Verbena*	x		
Viola cornuta	*Jonny-Jump-Ups*	x	x	moist areas
Viola tricolor	*Pansy*	x	x	
Zinnia linearis	*Linear zinnia*	x	x	

Dry areas = 10 to 30 inches rainfall/year

Moist areas = Over 30 inches rainfall/year

16:P:DP/IVM

Table 8.1

Class A Noxious Weeds

Common Name	Scientific Name
Bean-caper, Syrian	*Zygophyllum fabago*
Blueweed, Texas	*Helianthus ciliaris*
Buffalo bur	*Solanum rostratum*
Bursage, skeleton leaf	*Ambrosia tomentosa*
Chervil, wild	*Anthriscus sylvestris*
Cordgrass, salt meadow	*Spartina patens*
Crupina, common	*Crupina vulgaris*
Four o'clock, wild	*Mirabilis nyctaginea*
Hawkweed, mouse-ear	*Hieracium pilosella*
Hedge-parsley	*Torilis arvensis*
Johnsongrass	*Sorghum halepense*
Knapweed, bighead	*Centaurea macrocephala*
Knapweed, featherhead	*Centaurea trichocephala*
Knapweed, short-fringed	*Centaurea nigrescens*
Rosemallow, Venice	*Hibiscus trionum*
Nightshade, silver-leaf	*Solanum elaeagnifolium*
Peganum	*Peganum harmala*
Rupturewort	*Herniaria cineria*
Sage, Mediterranean (African)	*Salvia aethiopsis*
Snapdragon, dwarf	*Chaenorrhinum minus*
Starthistle, purple	*Centaurea calcitrapa*
Thistle, milk	*Proboscidea louisianica*
Velvet leaf	*Abutilon theophrasti*
Woad, dyers	*Isatis tinctoria*

Table 8-2

Class B Noxious Weeds

Common Name	Scientific Name	Physiographic Provinces
Broom, Scoteti	*Cytisus scoparius*	4,5,6,7,8
Bryony, white	*Bryonia alba*	1,2,3,4,5,6,7
Bugloss, common	*Anchusa officinalis*	1,2,3,4,5,6,7,8
Camelthorn	*Alhagi pseudalhagi*	1,2,3,4,5,6,7,8
Catsear, common	*Hypochaeris radica*	4,5,6,7,8
Cordgrass, smooth	*Spartina alterniflora*	1,2,3,4,5,6,7,8
Cordgrass, common	*Spartina anglica*	1,2,3,4,5,6,7,8
Daisy, oxeye	*Chrysanthemum leucanthemum*	4,5,7,8
Dead-nettle, hybrid	*Lamium hybridum*	1,2,3,4,5,6,7,8
Dogtailgrass, hedgehog	*Cynosurus echinatus*	4,5,6,7,8
Fieldcress, Austrian	*Rorippa austriaca*	1,2,3,4,5,6,7,8
Foxtail, slender	*Alopecurus myosuroides*	1,2,3,4,5,6,7,8
Goatgrass, jointed	*Aegilops cylindrica*	1,2,3,4,5,6,7
Gorse	*Ulex europecus*	2,3,4,5,6,7,8
Hawkweed, orange	*Hieracium aurantiacum*	4,5,6,7,8
Hawkweed, yellow	*Hieracium pratense*	1,2,3,4,5,6,7,8
Indigobush	*Amorpha fruticosa*	1,2,3,4,5,6,7,8
Knapweed, black	*Centaurea nigra*	1,2,3,4,5,6,7,8
Knapweed, brown	*Centaurea jacea*	1,2,3,4,5,6,7,8
Knapweed, diffuse	*Centaurea diffusa*	1,2,3,4,5,7
Knapweed, meadow	*Centaurea jacea x nigra*	1,2,3,4,5,6,7,8
Knapweed, Russian	*Centaurea repens*	1,2,3,4,5,6,7,8
Knapweed, spotted	*Centaurea maculosa*	1,2,3,4,5,6,7,8
Lepyrodiclis	*Lepyrodiclis holsteoides*	1,2,3,4,5,6,7,8
Loosestrife, purple	*Lythrum salicaria*	1,2,3,4,5,6,7,8
Loosestrife, wand	*Lythrum virgatum*	1,2,3,4,5,6,7,8
Nutsedge, yellow	*Cyperus esculentus*	1,2,3,4,5,6,7,8
Oxtongue, hawkweed	*Picris hieracioides*	1,2,3,4,5,6,7,8
Pepperweed, perennial	*Lepidium latifolium*	1,2,3,4,5,6,7,8
Ragwort, tansy	*Senecio jacobaea*	4,5,6,7,8
Sandbur, longspine	*Cenchrus longispinus*	1,2,3,4,5,6,7
Skeleton-weed, rush	*Chondrilla juncea*	1,2,3,4,5,6,7
Sowthistle, perennial	*Sonchus arvensis* var. *arvensis*	1,2,3,4,5,6,7,8
Spurge, leafy	*Euphorbia esula*	1,2,3,4,5,6,7,8
Starthistle, yellow	*Centaurea solstitialis*	1,2,3,4,5,6,7,8
Swainsonpea	*Sphaerophysa salsula*	1,2,3,4,5,6,7,8

Table 8-2 (Continued)

Class B Noxious Weeds

Common Name	Scientific Name	Physiographic Provinces
Thistle, musk	*Carduus nutans*	1,2,3,4,5,6,7,8
Thistle, plumeless	*Carduus acanthoides*	1,2,3,4,5,6,7,8
Thistle, Scotch	*Onopordum acanthium*	1,2,3,4,5,6,7
Toadflax, Dalmatian	*Linaria genistifolia* spp. *dalmatica*	1,2,3,4,5,6,7,8
Watermilfoil, Eurasian	*Myriophyllum spicatum* var. *exalbescens*	1,2,3,5,7,8

Table 8-3

Class C Noxious Weeds

Common Name	Scientific Name
Baby's breath	*Gypsophila paniculata*
Bindweed, field	*Convolvulus arvensis*
Carrot, wild (Queen Anne's lace)	*Daucus carota*
Catchfly, conical	*Silene conoidea*
Cocklebur, spiny	*Xanthium spinosum*
Hoarycress	*Cardaria draba*
Dodder, small-seeded alfalfa	*Cuscuta approximata*
Garden-rocket	*Eruca sativa*
Henbane, black	*Hyoscyamus niger*
Houndstongue, common	*Cynoglossum officinale*
Kochia	*Kochia scoparia*
Mayweed, scentless	*Matricaria maritima* var. *agrestis*
Mullein, common	*Verbascum thapsus*
Nightshade, bitter	*Solanum dulcamara*
Poison-hemlock	*Conium maculatum*
Puncture-vine	*Tribulus terrestris*
Rye, cereal	*Secale cereale*
Spikeweed	*Hemizonia pungens*
St. John's wort, common	*Hypericum perforatum*
Tansy, common	*Tanacetum vulgare*
Toadflax, yellow	*Linaria vulgaris*
Thistle, bull	*Cirsium vulgare*
Thistle, Canada	*Cirsium arvense*
Whitetop, hairy	*Cardaria pubescens*
Wormwood, absinth	*Artemisia absinthium*

17:P:DP/IVM

Appendix 9 — Sources of Information on Biological Control

An excellent handbook entitled *Field Guide to the Biological Control of Weeds in British Columbia* provides color photographs of 20 target weeds and their natural enemies — over 50 insects and pathogens. Most of the target weeds described are found in Washington State, and many of the natural enemies have been successfully established in the state as well. Biological information on the weed and its natural enemies is provided as are directions for collecting, releasing, and monitoring the biological control agents. This 163-page handbook is an excellent resource for maintenance crews interested in employing biological control methods. It is available from Crop Protection Division, BC Ministry of Agriculture, Fisheries, and Food, 17720 57th Avenue, Surrey, British Columbia, Canada V3S 4P9. Phone: 604/576-5600; Fax: 604/576-5652.

The *IPM Products and Services Directory* lists commercial producers of beneficial insects and other IPM-oriented pest control products. It is published annually by the nonprofit Bio-Integral Resource Center, P.O. Box 7414, Berkeley, California 94707; 510/524-2567, Fax 510/524-1758.

The following list of weeds and their natural enemies was compiled for British Columbia by R.S. Cranston, Provincial Weed Specialist, B.C. Ministry of Agriculture, Fisheries and Food. Most of these weeds are also found in the State of Washington. Many of the biological control agents listed here can be purchased from commercial sources listed in the *IPM Products and Services Directory.* Some biological control agents for weeds are also available from County Agricultural Commissioners.

Weed/Bioagent	Order	Attack Site
***Acroptilon repens* (Russian knapweed)**		
Puccinia acroptili	Uredinales	leaf
Subanquina picridis	Tylenchida	stem, leaf
***Carduus acanthoides* (Plumeless thistle)**		
Rhinocyllus conicus	Coleoptera	seedhead
Trichosirocalus horridus	Coleoptera	shoot
Urophora solstitialis	Diptera	seedhead
***Carduus nutans* (Nodding thistle)**		
Rhinocyllus conicus	Coleoptera	seedhead
Trichosirocalus horridus	Coleoptera	shoot
Urophora solstitialis	Diptera	seedhead
***Centaurea debauxii* (Brown knapweed)**		
Urophora jaceana	Diptera	seedhead
Puccinia centaurea	Uredinales	leaf

Weed/Bioagent	Order	Attack Site
Centaurea diffusa **(Diffuse knapweed)**		
Agapeta zoegana	Lepidoptera	root
Metzneria paucipunctella	Lepidoptera	seedhead
Pelochrista medullana	Lepidoptera	root
Pterolonche inspersa	Lepidoptera	root
Sphenoptera jugoslavica	Coleoptera	root
Subanquina picridis	Tylenchida	stem, leaf
Urophora affinis	Diptera	seedhead
Urophora quadrifasciata	Diptera	seedhead
Cyphocleonus achates	Coleoptera	root
Larinus minutus	Coleoptera	seedhead
Larinus obtusus	Coleoptera	seedhead
Centaurea maculosa **(Spotted knapweed)**		
Agapeta zoegana	Lepidoptera	root
Cyphocleonus achates	Coleoptera	root
Metzneria paucipunctella	Lepidoptera	seedhead
Pterolonche inspersa	Lepidoptera	root
Sphenoptera jugoslavica	Coleoptera	root
Urophora affinis	Diptera	seedhead
Pelochrista medullana	Lepidoptera	root
Terellia virens	Diptera	seedhead
Chaetorellia acrolophi	Diptera	seedhead
Larinus minutus	Coleoptera	seedhead
Larinus obtusus	Coleoptera	seedhead
Chondrilla juncea **(Rush skeletonweed)**		
Aceria chondrillae	Aracida	flower buds
Puccinia chondrillina	Uredinales	leaf
Cirsium arvense **(Canada thistle)**		
Altica carduorum	Coleoptera	leaf
Ceutorynchus litura	Coleoptera	shoots, crown
Urophora carduii	Diptera	stem
Larinus planus	Coleoptera	seedhead
Cirsium vulgare **(Bull thistle)**		
Rhinocyllus conicus	Coleoptera	seedhead
Urophora stylata	Diptera	seedhead
Trichosirocalus horridus	Coleoptera	shoot
Convolvulus arvensis **(Field bindweed)**		
Chirida guttata	Coleoptera	unknown
Metriona bicolor	Coleoptera	leaf
Aceria convolvulii	Acarina	stem, leaf
Cynoglossum officinale **(Hound's-tongue)**		
Mogulones cruciger	Coleoptera	root
Euphorbia esula **(Leafy spurge)**		
Apthona nigriscutus	Coleoptera	root
Apthona cyparissiae	Coleoptera	root

Weed/Bioagent	Order	Attack Site
Apthona flava	Coleoptera	root
Hyles euphorbia	Lepidoptera	leaf
Lobesia euphorbiana	Lepidoptera	leaf
Spurgia esula	Diptera	shoot tip
***Hypericum perforatum* (St. Johnswort)**		
Agrilis hyperici	Coleoptera	roots
Aplocera plagiata	Lepidoptera	leaf
Aphis chloris	Homoptera	stem, root
Chrysolina hyperici	Coleoptera	leaf
Chrysolina quadrigemina	Coleoptera	leaf
Chrysolina varians	Coleoptera	leaf
Zeuxidiplosis giardi	Diptera	leaf
***Linaria dalmatica* (Dalmatian toadflax)**		
Calophasia lunula	Lepidoptera	leaf
Brachypterolus pulicarius	Coleoptera	seed
Mecinus janthinus	Coleoptera	stem
Eteobalea intermediella	Lepidoptera	root
Gymnetron antirrhini	Coleoptera	seed, stem
***Linaria vulgaris* (Common toadflax)**		
Calophasia lunula	Lepidoptera	leaf
Brachypterolus pulicarius	Coleoptera	seed
Mecinus janthinus	Coleoptera	stem
Eteobalea seratella	Lepidoptera	root
Gymnetron linariae	Coleoptera	seed, stem
***Lythrum salicaria* (Purple loosestrife)**		
Hylobius transversovittatus	Coleoptera	root
Galerucella calmeriensis	Coleoptera	leaf
Galerucella pusilla	Coleoptera	leaf
***Matricaria maritima* (Scentless chamomile)**		
Apion hookerii	Coleoptera	seedhead
***Senecio jacobaea* (Tansy ragwort)**		
Hylemya seneciella	Diptera	seedhead
Longitarsus jacobaeae	Coleoptera	root
Longitarsus flavicornis	Coleoptera	root
Tyria jacobaea	Lepidoptera	leaf, stem
Cochylis atricapitana	Lepidoptera	root
***Sonchus arvensis* (Perennial sow-thistle)**		
Cystiphora sonchi	Diptera	leaf
***Tribulus terrestris* (Puncture vine)**		
Microlarinus lareynii	Coleoptera	seed, leaf

18:P:DP/IVM

How to Select an Herbicide for an IVM Program

The following criteria are presented for use when selecting an herbicide:

- Effectiveness
- Safety
- Mobility
- Residual life
- Selectivity
- Resistance

Effectiveness

In terms of achieving objectives, controlling costs, maximizing applicator safety, minimizing environmental impact, and reducing resistance problems, it is vital that the herbicide chosen be effective against the target organism and that it be applied at the correct rate under the correct weather conditions at the right time in the plants growth cycle. Otherwise, no benefit may be derived from the risks taken and resources used, and only unwanted side effects may result.

Safety

This means safety to the applicator, other humans, pets, livestock, wildlife, desirable vegetation, water quality and the overall environment. Although herbicides are formulated to be toxic to plants, they also can have negative impacts on beneficial insects, microorganisms, invertebrates, and mammals. Questions to ask include:

- What is label classification? Caution, warning, danger, etc.
- Acute (immediate) and chronic (long-term) toxicity. What is the LD_{50}[1] of the substance? Can or might it be carcinogenic (cancer-causing), mutagenic (causing genetic changes), or teratogenic (causing birth defects?)
- Are there hazards to fish or wildlife? What is the LC_{50}[2] for fish and aquatic invertebrates?

For a complete explanation and reference on herbicide safety refer to Washington Pesticide Laws and Safety, A guide to safe use and handling for applicators and dealers, publication MISC0056 available through Washington State University Cooperative Exention. Copies are also available to WSDOT employees through the Operations Service Center Maintenance Office.

Mobility

Is the compound volatile, so that it moves into the air? Can it move through the soil into the groundwater or run-off into surface waters? If so, is there a nonmobile material that can be substituted? What precautions can be taken to reduce mobility?

Residual life

How long does the compound remain toxic in the environment? How soon can desirable plantings be installed after use of the herbicide? How long will it be before another treatment is required to deter weed growth?

Selectivity

Does the herbicide affect a wide or narrow range of plant types? The most useful herbicides in an IVM program are those that have selective action. Such herbicides generally affect either broadleaved plants or grasses, but not both. Thus, a selective herbicide can facilitate establishment of desirable vegetation by only killing unwanted groups of plants. When nonselective, soil-residual herbicides are used, they should be applied as spot-sprays to the degree consistent with functional objectives in the roadside zone.

Resistance

A particular herbicidal material may have been effective against its target plants at the time it was registered, but if the plants are no longer responding to the material it may be a sign that the target vegetation has developed resistance to the pesticide.

Herbicide resistance is an issue of growing concern worldwide. Within the last 10 years, over 58 species of plants have developed resistance to the triazine class of herbicides alone (LeBaron 1991). Resistance develops when the same herbicide is applied repeatedly to a plant species. Some of the individual plants that are sprayed will have natural genetic resistance to the chemical compounds. Over time, if enough resistant individuals survive and reproduce, larger and larger populations of resistant weeds will take hold.

Four herbicide characteristics influence the risk of a weed developing resistance:

- A single mode of action
- Extreme activity and effectiveness in killing a wide range of weed species
- Long-term soil residual and season-long control of germinating weeds, or frequent applications during the year

- Applications over several growing seasons without rotating, alternating, or combining with other types of treatment tactics or herbicides.

To delay herbicide resistance, the following management techniques are suggested:

- Use herbicides as infrequently as possible
- Rotate herbicides or rotate herbicide use with alternative tactics; avoid herbicide rotations with similar modes of action
- Avoid or minimize use of long residual herbicides with a single site of action
- Use the lowest rate possible
- Avoid using herbicides with high risk for resistance; if they must be used, tank mix with other herbicides that affect the same target plants but have different modes of action.

In addition to becoming informed about the characteristics of the material itself, it is important to:

- Observe all application directions on the label
- Wear protective gear (neoprene gloves, goggles, respirator, hat and other protective clothing as necessary or required by law)
- Confine use of the material to the area requiring treatment (spot-treat)

Footnotes

1) LD_{50} is a rating of the acute toxicity of a material. It refers to the lethal dose (either oral or dermal) per kilogram of body weight required to kill 50 percent of the test animals (usually mice, rats, or rabbits). The lower the LD_{50} number, the higher its toxicity (i.e., it takes less material to show a toxic effect than a compound with a higher number).

2) LC_{50} is a rating of the acute toxicity of an herbicide to aquatic organisms selected for testing. The lower the number, the higher the toxicity of the material.

19:P:DP/IVM

WSDOT IVM Manual References

Aldrich, R. J. 1984. Weed-Crop Ecology: Principles in Weed Management. Bretchin. Belmont, CA. 465 pp.

Appleton, H.C. 1993. Alternatives to herbicide use at subject pole sites. Pacific Gas and Electric Co. Dept. of Research and Development. San Ramon, CA. 20 pp.

Bramble, W.C., W.R. Byrnes, and R.J. Hutnik. 1990. Resistance of plant cover types to tree seedling invasion on an electric transmission right of way. *Journal of Arboriculture* 16(5):130-135.

Bramble, W.C. and W.R. Byrnes. 1982. Development of wildlife, food and cover on an electric transmission right of way maintained by herbicides: a 30-year report. Research Bulletin #974. Dept. of forestry and National Resorces, Purdue univ., W. Lafayette, IN.

Comings, A. 1994. Fighting invaders with bare hands. *Fremontia* 22(3):30-31.

Conway-Brown, M. 1986. Update: Girdling — a nontoxic control for red alder. *The IPM Practitioner* 8(10):1-7.

Daar, S. 1994a. Integrated approaches to roadside vegetation management. *The IPM Practitioner* 16(9):1-8.

Daar, S. 1994b. New technology harnesses hot water to kill weeds. *The IPM Practitioner 16(3):1-5.*

Daar, S. 1991a. Biological control of aquatic weeds with sterile grass carp. *The IPM Practitioner* 13(9):1-6.

Daar, S. 1991b. Vegetation management on rights of way: an ecological approach. *The IPM Practitioner* 13(2):1-7.

Daar, S. 1986. Girdling — a nontoxic control for red alder. *The IPM Practitioner* 8(10):1-7.

Davis, E.S. and P.F. Fay. 1988. Seed longevity of spotted knapweed (*Centaurea maculosa). Proceedings of the Western Society of Weed Science* 41:75.

DeBell, D.S. and T.C. Turpin. 1989. Control of red alder by cutting. (Research Paper PNW-RP-414.) U.S. Forest Service, Pacific Northwest Research Station. Portland, OR.

del Moral, R. 1979. Ecological Control of Roadside Vegetation. Report to the Jefferson County, WA, Board of Commissioners. 31 pp.

Egler, F. 1953. Vegetation management for rights-of-way and roadsides. *Ann. report Smithsonian Inst.* Pub. No. 4149. Washington, D.C. 400 pp.

Gliessman, S.R. and C.H. Muller. The phytotoxic potential of bracken, *Pteridium aquilinum. Madrono* 21(5):299-304.

Isacson, D. and H. Radtke. 1993. An economic evaluation of biological control of tansy ragwort in western Oregon. IN: *Proceedings of the Oregon Society of Weed Science*, 18-19 October 1993, Clackamas, OR, pp 3-4. Oregon Society of Weed Science, Corvallis, OR.

Larson, M.M. and E.L. Schwartz. 1980. Allelopathic inhibition of black locust, red clover, and black alder by six common herbaceous species. *Forest Science* 261(3):511-520.

McEvoy, P.B. and N.T. Rudd. 1993. Effects of vegetation disturbaces on insect biological control of tansy ragwort, *Senecio jacobaea. Ecological Applications* 3(4):682-698.

Müller-Schärer, H. and D. Schroeder. 1993. The biological control of *Centaurea* spp. in North America: Do insects solve the problem? *Pesticide Science.* 37:343-353.

Nechols, J.R. et al. eds. 1995. Biological control in the western United States. Univ. of Calif. Div. of Agric. and Natr. Res. Pub. No. 3361. Oakland, CA. 356 pp.

Orians, G.H. 1986. Site characteristics favoring invasions. IN: Mooney, H.A. and J.A. Drake, eds. Ecology of biological invasions of North America and Hawaii. Springer-Verleg, New York. Pp 133-148.

Peters, E.J. and A.H.B. Zam. 1981. Allelopathic effects of tall fescue genotypes. *Agronomy Journal* 73:56-58.

Powell, G.W., A. Sturko, B.M. Wikeem, and P. Harris. 1994. Field guide to the biological control of weeds in British Columbia. British Columbia Ministry of Forests. Available from: Crown Publications, Inc., 546 Yates St., Victoria, B.C. V8W 1K8, Canada. P. 79.

Prull, G. 1989. *Inventory and prescriptions for management of roadside vegetation.* Final Prescriptions Report for Gifford Pinchot National Forest. Contract No. S3-OSK3-8-059801.

Rice, E. L. 1972. Allelopathic effects of *Andropogon virginicus* and its persistence in old fields. *American Journal of Botany* 59(7):752-755.

Rogers, D. 1981. Notes on planting and maintenance of bunchgrasses. *Fremontia* 9(1):24-28.

Shigo, A. 1986. A new tree biology: facts, photos, and philosophies on trees and their problems and proper care. Shigo and Trees, Associates. Durham, NH. 595 pp.

Smith, D.D. 1994. Integrated roadside vegetation management: the Iowa model. *Roader's Digest* 6(1):3-4.

Sousa, W.P. 1984. The role of disturbance in natural communities. *Annual Review of Ecology and Systematics* 15:353-391.

Story, J.M. et al. 1991. *Metzneria Paucipunctella* Zeller (Lepidoptera: Gelechidae), a moth introduced against spotted knapweed: It is feeding strategy and impact on two introduced Urophora spp. (Diptera: Tephritidae). *The Canadian Entomologist.* 123:1001-1007.

Swan, D.G. et al. 1980. Weed control on rights of way. Washington State University Cooperative Extension Service, Bullentin 0669. Pullman, WA. 27 pp.

White, P.S. 1979. Pattern, process, and natural disturbance in vegetation. *Botanical Review* 45:229-299.

WSDOT. 1994. *Draft Guidelines for Implementation of A Modified Zone 1*. WS-DOT Document 9 pp.

WSDOT. 1993a. *Zone 1 Roadside Vegetation Management Implementation Task Force Study*. WSDOT Document. 15 pp.

WSDOT. 1993b. *Final Roadside Vegetation Management Environmental Impact Statement.* WSDOT, Olympia, WA.

WSDOT. 1993c. *Draft Roadside Vegetation Management Environmental Impact Statement.* Appendix A. pp. A7-29.

20:P:DP/IVM

Action Preparation Time — The amount of time required to prepare for a given *treatment.*

Action Threshold — The point when the number, area of cover, or quantity of some plant characteristic reaches a level when treatment action must be taken to avoid reaching the *injury level*.

Allelopathy — When a species of plant produces compounds toxic to other plants. These toxins prevent other plants from growing nearby and competing for water and nutrients. Toxins may be exuded from roots or stored in leaves which form a skirt of toxic litter around the base of the plant when they fall.

Cover — The amount of area a plant occupies, usually defined as a percentage of a fixed area chosen by the observer. An individual plant is considered to cover all of the area within the outline defined by its canopy.

Current Conditions Information — Information about the physical, biological, and managerial conditions of a roadside area. It is gathered repeatedly over time as part of a *monitoring* program.

Decision Point — The point in time when a decision about a *treatment* must be made and plans for action should start if intolerable damage is to be prevented.

Desirable Vegetation — Persistent and hardy plant species which compete with unwanted plants, especially weeds, but either support *functional objectives* or have no effect on them.

Ecological Objective — A specific objective set by WSDOT policy to minimize the environmental impact of roadside maintenance activities.

Focus Area — An area of roadside where conditions must be subject to *monitoring* for *management goals* to be reached. Focus areas are where monitoring efforts are concentrated.

Functional Objective — A specific objective set by WSDOT policy to meet the *overall objectives* of providing safe mobility and maintaining good neighbor relations.

Growth Stage — A recognizable stage in the growth sequence of a plant (germinating, flowering, setting seed, dying back, etc.).

Injury Level — The number, area of *cover*, or quantity of some plant characteristic which will cause unacceptable functional, economic, aesthetic, or environmental damage when reached by a type of vegetation.

IVM — A decision-making and management process which includes integration of multiple management techniques with a monitoring and evaluation system, understanding of the *functional goals* for management, understanding of the role of vegetation management in the overall management system, and knowledge from a broad base of expertise and the experience of personnel.

Management Objective — The specific objectives or goals set for achieving *functional and environmental objectives* through daily maintenance activities.

Model Areas — A specific site where an intentional planting or spontaneous community of *desirable vegetation* has established and persisted. Model areas provide opportunities to learn new techniques for establishing desirable vegetation.

Monitoring — Gathering information about vegetation management through repeated observations of a roadside area over the course of a season.

Natural Succession Species — Selected species of plants native to Washington State which belong in the plant community of a given roadside area and contribute to the formation of stable, *desirable plant* communities on that site.

Overall Objective — A general, guiding principle which helps define the purpose of the WSDOT Vegetation Management Program.

Problem Area — An area of roadside where repeated vegetation problems have occurred historically or a new, severe problem has developed. A problem area is a type of *focus area* receiving priority in *monitoring* efforts.

Qualitative — General or descriptive. Qualitative information involves characterizing plants by using terms such as “tall,” “short,” “vigorous,” etc.

Quantitative — Specific and involving a measured amount of something. Quantitative information involves measuring plant characteristics such as height, percentage of ground covered, number of plants present, stem diameter, etc.

Sensitive Area — A specific site with *functional objectives* above and beyond those typical for each roadside zone.

Site Background Information — Historical information about an area of roadside. It is gathered once at the beginning of the development of an *IVM* program for the area.

Spot Treatment — Applying a *treatment* to the target only rather than over a broad area containing the target.

Strategy — An overall approach to solving vegetation problems. Strategies consist of families of management *tactics*.

Tactic — A particular type of approach to solving vegetation problems. Tactics are the basic ingredient in specifying *treatments*.

Test Area — A specific site set aside to test the effect of *treatments*. A test area receives specific treatments, includes an plot which receives no treatments at all, and is carefully monitored.

Treatment — A detailed and specific plan on exactly how and where vegetation management actions will be applied and exactly what those actions will be. Treatments are specified by considering the site, the target species, the *management objectives* for the site, and many other factors which must be considered for treatment actions to be successful.

Treatment Timing — The point in time in a target plants growth cycle, the management schedule, or other important sequence when a *treatment* must be applied to be successful.

Treatment Rate — The quantity of a *treatment* needed for the treatment to be successful. This could include mowing height, brush-cutting height, depth of mulch applied, pounds of seed per acre of roadside, amount of active ingredient per acre, etc.

Treatment Placement — The exact area where a *treatment* is applied. In *IVM*, treatments are placed as *spot treatments*.

Truck Transect — Gathering *monitoring* information about *current conditions* by driving along a designated rout and sampling periodically.

Typical Area — A site with vegetation which is typical of many other roadside segments and can be *monitored* to indicate conditions in other parts of the roadside maintenance system.

Vegetation Management Objective — The specific objectives or goals set for achieving *functional and environmental objectives* for roadside vegetation through daily maintenance activities.

Visual Packing — Quantifying the percentage area covered by a species of plant by framing an area and, in your minds eye, moving or packing all of the individuals of that species into one corner of the frame and estimating how much of the frame this imaginary patch fills.

21:P:DP/IVM